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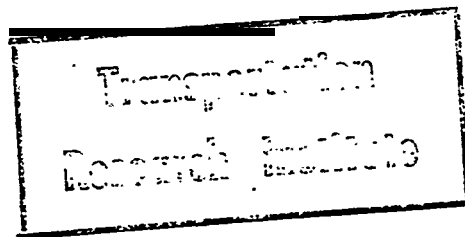
NSRP 0201

71684

A REPORT TO BATH IRON WORKS CORPORATION  
O N  
SHIP PRODUCIBILITY AS IT RELATES TO  
SERIES PRODUCTION

V O L U M E I I I

SHIP PRODUCTION PROCESS



INGALLS SHIPBUILDING  
P O Box 149 Pascagoula Mississippi 39567

SUBMITTED TO:  
BATH IRON WORKS CORP.  
BATH, MAINE  
20 OCTOBER 1975

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**VOLUME III**

**PART 1**

**FACILITY UTILIZATION**

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## FACILITY UTILIZATION

### 1.1 INTRODUCTION

To fully realize the benefits of a series production program, the shipyard must adjust to a series production mode of operation which will optimize the utilization of the fixed facility characteristics.

The general approach recommended in achieving this objective is to establish a balance of capabilities throughout the production facility, as required to adequately support production of a given series of ships.

To accomplish this goal, four major task items have been identified which, when properly accomplished, will assure a coordinated and well prepared approach to a series production program.

The four (4) major topics included are:

- a. The Product Design Effort
- b. The Facilities Capability Manual
- c. The Stationization Plan
- d. The Manufacturing Plan.

While the above items are not necessarily new to shipbuilding, the level of detail recommended for these topics and the emphasis *given* to the specific detail planning, is in excess of that detail normally required to support single ship construction.

While there is evidence that these tasks are being accomplished to some degree by the majority of the major U. S. shipyards, their implementation is at best fragmented, incomplete and underpublicized *within the* individual shipyard organizations as compared to similar efforts accomplished by nonmarine industries. This difference in implementation is not justifiable in terms of numbers to be built or duration of contract, and while the benefits from application of the principles may be somewhat greater in other industries, the principles are still valid for shipbuilding. Reorientation within the shipbuilding community to implement these techniques appears to be economically sound, and is highly recommended for series type production.

Accomplishment of these tasks will most likely require that additional span time be allowed for *their* preparation and completion prior to the *start* of actual production. (See Production Planning, Volume III, Part 4, *paragraph* 4.9. )

The importance of this requirement for adequate lead time to accomplish an expanded engineering and planning effort is directly related to successful facility utilization, and cannot be over emphasized for series production.

## 1.2 PRODUCT DESIGN

The objective of the product design effort is to reduce ship production costs by increasing the compatibility between the finalized ship design and the production capability of the shipyard.

This program, when satisfactorily implemented, will assure that every effort has been made in *Engineering to tailor the* ship design to suit the unique characteristics of the individual production areas and shops which combine to make up the total shipyard facility.

When the ship design requires departures from the existing shipyard capability, the product design effort will identify the departure and establish the most practical solution, such as procurement of new equipment, subcontracting, or adoption of an alternate course of action.

The implementation of this program *is* intended to be a continuous effort throughout the design process. and should include a Product Design Review for each of the major design disciplines.

Where the ship design has been developed by a design agent long before the construction contract is awarded, the shipyard engineering and production planning staff must still work together to develop product design refinements prior *to the start* of fabrication. In either case, the additional effort accomplished (once ) at this time will produce repeated benefits throughout the series production contract which will more than *justify* the additional costs incurred, if any.

Since all elements of the ship design represent some combination of factors which can be adjusted to the benefit of production, no attempt has been made as a part of this study *to* identify product design candidate items, or furnish guidance in the manipulation of design features which must be accomplished to adjust the design to a specific facility.

Hopefully, shipbuilders will encourage the application of this effort within the environment *of* their respective facilities, and address the implementation of this subject in the context of actual shipbuilding programs either now in progress or anticipated in the future.

#### 1.2.1 Drawing Preparation as Related to the Product Design Effort.

As a part of the product design effort, particular attention should be given to the methods used to prepare the production drawings and the completeness of the information as released to production.

Extensive use of tabulations, tables and matrixes should be avoided whenever possible, since the drafting time saved in engineering does not justify the additional time required in production to analyze the tabulations and extract the necessary information. Tabulations also contribute to manufacturing errors, particularly after drawings become worn and hard to read, and while this is no fault of the draftsman, it is a factor *which* should be emphasized by the product design team during the plan preparation period.

System *drawings or* other drawings which include a high content of information unrelated to production should not be used to support production even in a modified form (See "Instructions, " Volume II, Part 7. )

Wherever possible, all dimensions and related information required for the manufacture of a single part, subassembly, or major assembly should be included on a single drawing. References to other drawings or external information sources should be held to a minimum"

Dimensional requirements should be reviewed and tolerances established which are well within the capabilities of the production facility and work force. Care should be taken to insure that features used as dimensional constraints are in fact included on the dimensioned object at the time of manufacture and/or assembly.

Reference to a *datum*, plane or surface, such as a deck level or tank top, which is inaccessible at the time of installation causes a *great* deal of lost time in production, and drawings should be reviewed to eliminate this practice.

While good drafting practices are always encouraged, many of the malpractices mentioned do occur on drawings released for production, and since the benefits derived from a well-prepared drawing are multiplied in series production, this area of the product design effort should receive particular and continuous attention.

#### 1.2.2 Accomplishment of the Product Design Effort.

One approach to the accomplishment of the product design is to temporarily assign production planning personnel (who would normally be waiting for the engineering drawings to be developed) to Engineering as an early-planning or head-start production task force. The close liaison between engineering and planning which is created at this time will be carried over to the production phase of the *program*, expanding the lines of communication and encouraging the incorporation of production considerations during the later phases of the program.

With this approach, the product design 'team acts primarily as a liaison between Engineering and Production, with the objective of reducing the time required to accomplish the planning effort coupled with the objectives of the product design effort.

As an alternate approach, a product design function can be established within the engineering organization. Personnel who are experienced in the workings of a particular craft and are thoroughly familiar *with the* manufacturing equipment associated with that craft can be organized into a small but effective force which can accomplish the product design effort *initially*, and then support method improvement and similar innovational efforts on a sustained basis for the duration of the program.

Whatever the approach, the establishment of an independent function, primarily concerned with production considerations, should be included in the engineering plan development cycle so as to ensure the optimum use of the facility and the most beneficial approach to plan preparation and presentation methods.

### 1.3 THE FACILITY CAPABILITY MANUAL

In order to emphasize facility considerations during the design process, it is first necessary to define the fixed characteristics of the various equipments and shops which make up the total shipyard production capability.

This information, once formulated, can then be utilized by the Engineering Planning and Material Departments to tailor the ship design characteristics to suit the shipyard facility.

To accomplish this task, it is recommended that each shipyard prepare a comprehensive Facility Capability Manual which describes the functions, capacities and limitations of all major equipments, down to the level of detail required to support both the design effort in engineering and the production planning effort which follows. If

similar information has already been prepared by separate organizations of the shipyard, it is recommended that the information be reviewed, verified and updated periodically. The manual should then be distributed generously throughout the respective design and production planning organizations.

The recommended *outline* for the *manual* is shown in figure 1-1. Preparation of the manual is diagramed in figure 1-2.

In many cases, the preparation of this manual requires little more than collecting and compiling data which, for the most part, is readily available but unfortunately has been underpublicized within the shipyard. As part of the series production mode of operation, these lines of communication must be established and expanded as required to establish the coordination and team work essential to effective series production.

While it is recommended that the data describing the total facility capability be compiled into a single document, it is recognized that only portions of this information are required by a specific engineering discipline or planning group, and that partial capabilities distribution may be more economical and practical in some instances.

A secondary benefit of the Facilities Capability Manual is that the information contained therein serves as a valuable reference for an outside naval architectural firm engaged in the design of a ship which may be constructed at that particular shipyard. By emphasizing the yard's potential for reduced construction costs naval architectural firms are enabled to develop designs which are commensurate with existing shipyard capabilities and more suitable for series-type production.

SECT. 1	GENERAL DESCRIPTION
	OVERALL PLOT PLAN DETAILED DESCRIPTION OF LAUNCHING WAYS, GRAVING DOCKS, ETC DEEP WATER CHANNELS AND SURROUNDING WATER DEPTHS
SECT. 2	DESCRIPTION OF INDIVIDUAL SHOPS AND PRODUCTION AREAS
	“KEY” PLAN SHOWING GENERAL LOCATION FLOOR PLAN OF EACH SHOP - EQUIPMENT ARRANGEMENT CORRESPONDING EQUIPMENT LIST WITH CAPACITY/CAPABILITY DATA MATERIAL HANDLING EQUIPMENT SHOP CRANE LOCATIONS, TRAVEL, CAPACITIES AND REQUIRED CLEARANCES UTILITIES - ELECTRICAL, GAS, COMPRESSED AIR, ETC. UNIQUE FEATURES - DOOR CLEARANCES, OBSTRUCTIONS, ETC.
SECT. 3	MASTER CRANE LIST
	CRANE LISTING BY LOCATION INDIVIDUAL CRANE DESCRIPTION -
	POWER, TYPE, REACH, CLEARANCE CAPACITY - LOAD/MOMENT OR EQUIV. MAX. HOOK HEIGHTS
SECT. 4	SPECIAL TOOLING CATALOGUE
	HAND TOOL AND PORTABLE TOOL CATALOGUE LIFTING BEAMS AND RIGGING APPARATUS SPECIAL TOOLING JIGS FIXTURES

Figure 1-1. Facilities Capability Manual Outline

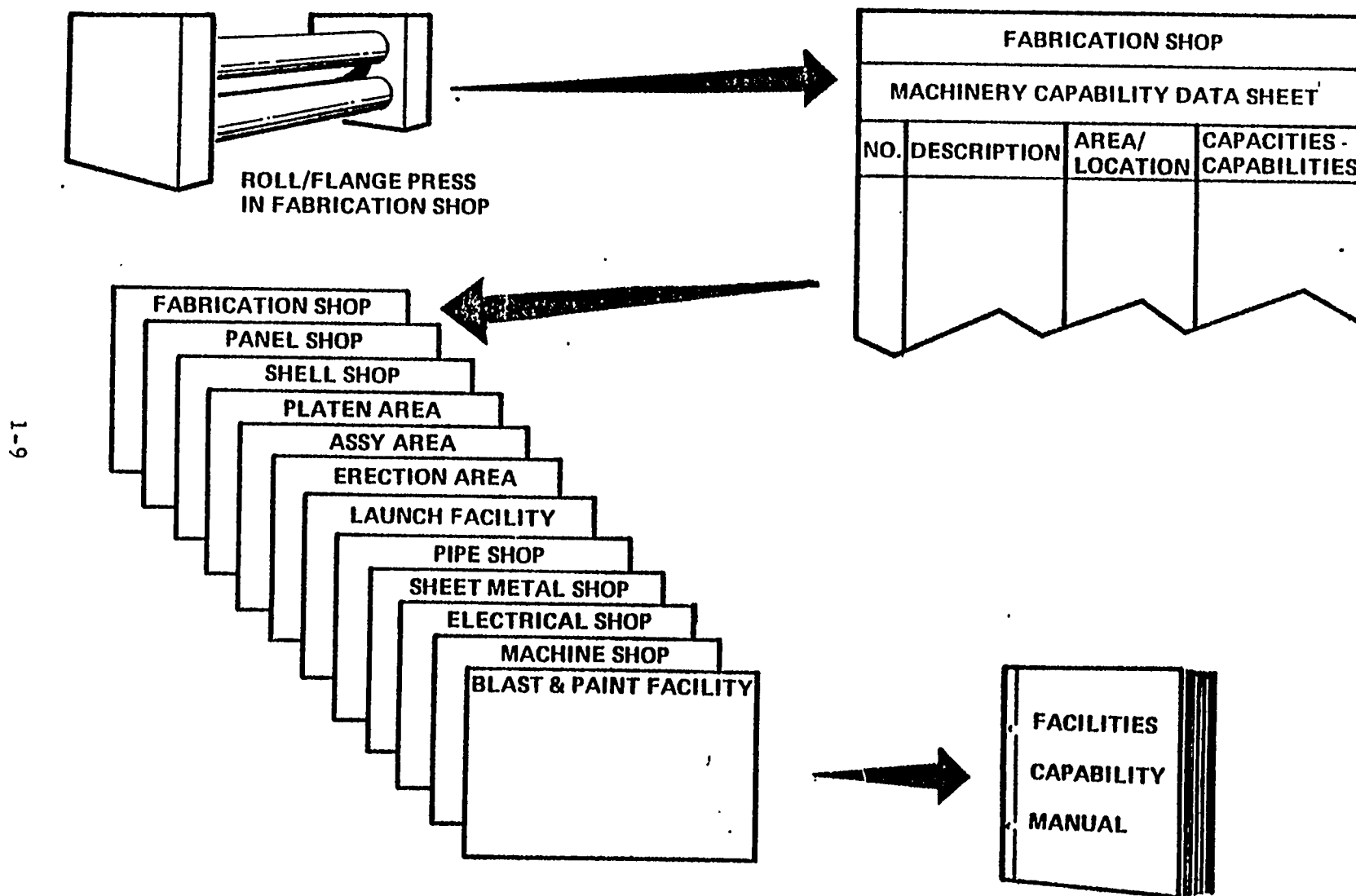


Figure 1-2. Preparation of the Facilities Capability Manual

#### 1.4 THE STATIONIZATION PLAN

In addition to the production planning normally accomplished in support of single-ship production, a more comprehensive Stationization Plan is required which coordinates and integrates the rates and cycles of all discrete tasks anticipated for series production.

The objective of the Stationization Plan is to optimize the use of the total resources which make up the shipyard facility and to regulate the production flow through the facility as required to minimize disruptions and insure a coordinated production effort.

With its inherent potential for more efficient accomplishment of repetitive operations, the series production Stationization Plan is considered to be one of the key elements necessary for good facility utilization.

Figure 1-3 represents the structural assembly portion of a stationization plan for a nine ship series production contract.

As a result of the plan development, 21 discrete work station areas were established, as required to insure that the same structural unit was assembled at a constant location for all ships of the series. The work content at each station was analyzed, and the proper planning required to support the work station concept was applied in each case. (See Volume III, Part 3.)

The example is considered to successfully demonstrate the visibility which must accompany the successful series production manufacturing effort.

The four-digit number accompanying each bar in the schedule portion of the chart is the assembly identification number and is explained as follows:

(x)    (xxx)

Hull Number  
(Single Digit)

Assembly Number  
(Three Digits )

Note that by reading from left to right, the hull number changes while the assembly number remains the same, reflecting the construction of the same unit at a given work station.

This basic work station plan contributes to a *number* of subsequent planning and evaluation efforts, including the following typical support considerations:

- a. Manpower planning
- b. Tooling requirements
- c. Transportation equipment requirements
- d. Crane capacity and utilization requirements
- e. Material kitting, storage and handling requirements
- f. Utilities -( compressed air, welding gases, electric power)
- g. Weather protection requirements

h. Development of schedules for support type activities:

- (1) Blast and painting
- (2) Pre -outfitting of pipe, sheetmetal, electrical
- (3) Heavy lifts
- (4) Inspection and quality assurance
- (5) Manufacturing services (blocking, shoring, scaffolding, temporary lights, heat and blowers )

The Stationization Plan is also required to establish optimum cycle times for the fabrication of major components when similar units are being manufactured for either the same ship or, as in the case of series production, for a number of successively constructed ships.

Since preparation of the Stationization Plan is dependent upon completion of the basic production planning effort, it is probable that accomplishment of this task will extend the overall span time required for preproduction planning to some extent. However, by developing this plan in parallel with the routine planning effort, the over- all additional time required can be minimized.

The anticipated benefits of the Stationization Plan are summarized as follows:

- o Coordination of production rates through the individual work stations located within the shops and throughout the various shipyard areas.

- o Establishment of facility utilization requirements for steady state production, including space, equipment and tooling.

l Cost avoidance benefits as associated with:

- a. Minimizing number of jigs and fixtures required
- b. Minimizing amount of in-process storage space required
- c. improving production flow, shorter travel distances, easier handling of major items
- d. Improving material staging and kitting to minimize lost material and lost time due to material shortages
- e. Implementation of weather protection improvements, in recognition of minimal requirements for individual work station areas
- f. Increased amount of pre- outfitting
- g. Improved manpower utilization
- h. Development of more accurate cost-collection data
- i. Earlier identification of problem areas and more detailed evaluation of performance to schedule and budget allocations
- j. Increased amount of learning carried over to follow-on construction programs.



Preparation of the plan will vary to suit the individual requirements of the shipyard, but it is recommended that the complete plan include the following information as a minimum:

- a. Ship completion and launch schedule (s)
- b. Identification and scheduled usage of building positions - (building ways, graving dock, etc. )
- c. Erection sequences and erection schedules for each hull, by assembly or unit
- d. Specified locations for assembly of all major structural units with corresponding schedule of completions to establish "cycle" times for each unit
- e. Lay-down plan for the location of all structural jigs and fixtures, with corresponding scheduled usage information
- f. Fabrication rate for detailed structural elements such as stiffeners, gussets, floors and girders (establish quantities and schedules for batch or lot release).

With the hull fabrication and erection portions of the Stationization Plan completed, stationizing efforts can be expanded to optimize the installation of pre- outfitting items and to incorporate methods improvement-features in that portion of the detailed planning which controls operations to be performed at individual stations or work areas.

## 1.5 THE MANUFACTURING PLAN

The Manufacturing Plan is a detailed plan of action which formulates the requirements generated by a specific shipbuilding contract and which establishes the sequence of events in the production process as planned *for* the execution of that contract.

Although the primary use of the plan is its implementation after contract award, preliminary plans serve as a valuable marketing tool, by emphasizing the shipyards capability to successfully complete a given program.

Development of the plan should start as early in the precontract phase as possible, with full recognition that at this point it may be necessary to incorporate certain assumptions which will require *clarification at* a later date. By forcing a detail level planning effort as early as possible, inadequacies which might exist will be identified earlier and plans for corrective action can be developed on a contingency basis. In the *event* of a contract award, preparations for the orderly transition to the new production contract can be accomplished more efficiently and with a minimum amount of disruption to the production routine.

Once completed, the manufacturing plan acts as a bridge between the various production and production support groups which must work as a team to develop the coordination required in series production. In a sense, learning is expedited on a large scale, by forcing agreement and understanding at an earlier stage than is normally associated with single- ship construction.

While it is difficult to stipulate the specific benefits derived from development and use of the plan in the successful production operations, it is quite easy to identify the problem areas and disruptive operations which can be eliminated by application of the plan to a *struggling* production effort. Improvements gained by use of this technique have made it a permanent technique practiced in major nonmarine industries and the increased emphasis on series production in shipbuilding is viewed as a direct requirement for the adaptation of this technique.

#### 1. 5.1 Contents of the Plan.

Figure 1-4 represents the basic outline for the manufacturing plan of a 150, 000 DWT tanker. The contents may be expanded to include the unique requirements generated by a specific contract or adjusted so as to enhance concurrent preparation by independent parties or organizations, but should not be reduced in scope in an effort to shorten the time required for preparation.

In Section 1 the basic schedule parameters and requirements are established in sufficient detail to support later shop-loading analyses and facility utilization planning.

Section 2 describes the basic product. The section *is* prepared by engineering and production planning, and essentially describes the ship characteristics and the intended hull structure break- down.

In Section 3, the information contained in the foregoing sections is utilized to synthesize the product through the manufacturing facility. Individual equipments, shops and work areas are analyzed and loaded as required to meet the production schedules. The Stationization Plan, as previously described, becomes the major guide in developing this section, where each individual work area is laid out in detail and the work content is cycled as required to meet the overall production schedule.

## MANUFACTURING PLAN OUTLINE

SECTION 1	INTRODUCTION AND PROGRAM DEFINITION  SCHEDULED DELIVERIES & BUILD SEQUENCE KEY EVENTS SCHEDULE BUILDING POSITION /LAUNCH SCHEDULE
SECTION 2	PRODUCT DESCRIPTION AND ENGINEERING BASELINE  SHIPS DESCRIPTION, CHARACTERISTICS MANUFACTURING WORK BREAKDOWN STRUCTURE PRINCIPAL FUNCTIONAL AREAS OF SHIP UNIQUE DESIGN CHARACTERISTICS
SECTION 3	MANUFACTURING PLAN  STATEMENT OF WORK STEEL REQUIREMENTS /ALLOCATIONS FABRICATION SEQUENCE STATIONIZATION PLAN ERECTION SEQUENCE PAINT & COATINGS PLAN MACHINERY PLAN OUTFITTING PLAN TEST & TRIALS PLAN TOOLING REQUIREMENTS MAKE OR BUY - IDENTIFICATION OF MAJOR PROCUREMENTS QUALITY ASSURANCE PROGRAM
SECTION 4	FACILITIES  AVAILABILITY , CAPABILITIES SCHEDULES, SHOP LOADING MATERIAL & INVENTORY CONTROL MANUFACTURING SERVICES REQUIREMENTS IDENTIFICATION OF NEW OR UNIQUE REQUIREMENTS
SECTION 5	PROGRAM FORECASTS  MANNING REQUIREMENTS SOFTWARE & SUPPORT REQUIREMENTS CAPITAL ACQUISITION PLAN

Figure 1-4. Manufacturing Plan Outline

In Section 4, the plan as developed for the new contract is merged with existing contracts and with other work on hand. Earliest possible start dates are established and shop-loading is adjusted so as to phase in the new contract while minimizing requirements for major machine utilization adjustments. Peak loading within the shops is analyzed to assure adequate machine and tooling capabilities.

The existing work force is analyzed by craft in Section 5. Manpower forecasts generated by the existing work-load are adjusted to show additional manpower requirements, if any, and to extend durations of manpower requirements as required by the forthcoming construction program.

Section 5 also outlines any facility modifications and new equipment requirements which would be necessary to implement the anticipated program. The Capital Acquisition Plan should include justification data, such as trade-off studies, historical cost data, etc. , as required to support acquisition of new equipments as well as a detailed estimate, time phased, for all anticipated facility modifications.

#### 1. 5.2 Manufacturing Plan Benefits.

It is the intent of the manufacturing plan to emphasize detail level planning as early as possible for a given shipbuilding program. While most shipyards presently accomplish the outlined tasks in one form or another, these efforts are usually completed late in the planning stages, and are rarely compiled and circulated for review and comment. In contrast to a series of fragmented efforts, the comprehensive plan will identify coordination or support inadequacies and corrective action can be incorporated early enough to minimize the threat of disruption.

In addition, the team effort generated during the preparation of the plan will help to create understanding and perspective conducive to the success of the oncoming program. The confidence gained by being ready and the elimination of surprises is a major advantage affecting production efficiency during the program. Management or supervisory personnel changes which take place during the program are assimilated more easily, and dependence on key personnel is diminished. Since the plan is basically intended as a management tool, distribution should be limited, although distribution of applicable sections, to be used for specific purposes, may prove to be practical in specific areas.

After completion of the program, the plan acts as a recorded history for the accomplishment of the contract, and future efforts of a similar nature may benefit from the past experiences documented in the plan.

## 1.6 SUMMARY

Facility utilization is an extensive subject which represents a major area of potential for the reduction of ship production costs. By improving the utilization of the existing capabilities of a shipyard, new requirements can be minimized, capital expenditures for additional equipment are limited, and production through-put is regulated to suit the capability of specific shops and work areas.

Where the opportunity exists, facility considerations can contribute to the development of the ship design, as required to optimize its potential for producibility at a specific shipyard.

Whether applied to an existing design or one which is under development, the mechanisms outlined should produce beneficial results which will ultimately reduce construction costs and improve production reliability. The increased interest in series production which has developed in shipbuilding in recent years represents a significant opportunity for the application of these techniques, which, hopefully, will be adopted and utilized to the benefit of the industry.

VOLUME III

PART 2

PRODUCTION AREAS AND SHOPS

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VOLUME III  
PART 2  
PRODUCTION AREAS AND SHOPS

2. 1 INTRODUCTION

As a result of preliminary investigations associated with the development of the Mid-Ship Section configuration portion of the study (Volume II, part 1), five structural elements of a 150, 000 DWT tanker were chosen for investigation related to series production in a fabrication area:

- a. Floors
- b. Girders
- c. Brackets
- d. Small panels
- e. Large panels

These items were chosen as being representative of the major content of the parallel mid-body hull structure, and for their commonality within the variances of each mid-ship section configuration.

For each of these items, the method of fabrication was analyzed for single and series ship production, and the respective costs were developed for comparison purposes.

The cost trade-off methodology for conventional shop production of single - ship elements (without the use of automated lines) was developed through the use of historical data as developed at Ingalls '

(conventional) East Bank facility, Which is considered to be fairly representative of the conditions in existence for single-ship production at most shipyards.

The equivalent manhour requirements for series production were developed utilizing the recommended speeds and feed rates for the equipment proposed, and returned cost data developed at Ingalls ' West Bank (automated/module) shipyard, as applicable.

In some cases, manhour requirements were reduced or expanded as required *to* incorporate the effects of unavoidable idle time or line-balancing considerations.

AU special tooling and equipment costs required for series production, including fabrication and installation labor, are included in the total cost for the first ship of the series. For the purposes of establishing total cost savings and projecting the various break-even points, it was assumed that ten shipsets would be produced.

In reconciling the effects of learning, a 92% standard learning curve was applied to all situations reflecting the accomplishment of repetitive operations, for both single ship and series -ship production.

- (1) Cost of building one shipset of a particular product without special tooling and equipment.
- (2) The cost of special *tooling*, material and equipment associated with series production.
- (3) Cost of building one shipset of the subject product utilizing special equipment and tooling plus the cost of the special equipment, material and tooling.

- (4) Cost of ten shipsets of the product without special equipment and tooling.
- (5) Cost of ten shipsets of the product utilizing special equipment and tooling plus the initial cost of the special equipment and tooling.

In each case, a summary of costs is *also* provided, and the "break- even" ship has been identified, indicating the number of ships which must be anticipated in order to justify the capital expenditure associated with the respective automated installations.

## 2.2 FABRICATION OF FLOORS AND GIRDERS

In evaluating the fabrication of the *floors* and girders, the study was developed on the following basis:

- a. Fabrication would take place on a platen for single-ship production;
- b. Fabrication would take place on an automated conveyor line for series production.

In the platen estimate, the time required for layout is included in the manhours allocated for fitting, and the time allocated for material handling is considered to be conservative since it does not consider the "extra" moves that actually take place as part of the normal shifting of material to suit everyday conditions.

In the automated conveyor estimate, the dwell time at each functional station was fixed at one and one half hours, and manned accordingly.

The detailed estimates, reflecting the direct labor costs associated with the two alternate production methods are derived for girders only, since the basic work content and structural configuration similarities do not warrant the preparation of a separate cost estimate for the floors.

The derivation of these estimates is given for single ship and for series ship production.

a. Single Ship Process - Direct Labor Estimate

(1) Material Description

150 girders 15' x 48' x 5/8" (2 plates 7 1/2')

1800 stiffeners 5" x 4" x 1/8" (15 long)

(2) Process

(a) Burn girder plates on flame planer or burning machine (4 plates simultaneously).

(b) Stiffeners to be purchased.

(c) Move girder plates to platen area

(d) Fit and tack plates

(e) Weld plates 1st side

(f) Fit and tack stiffener

(g) Weld "stiffeners

(h) Turnover

(i) Gouge plates 2nd side

(j) Weld plates 2nd side

(k) Load completed girder and store

(3) Calculations:

(a) Burning:

Burn 300 plates (4 simultaneously) @ 1.6 hrs  
x 2 men.

$$300 \div 4 \times 1.6 \times 2 = 240.0 \text{ manhours}$$

(b) Plate Fitting:

Fit 2 7 1/2' x 48' x 5/8" plates @ .0731 manhours  
per foot.

$$300 \div 2 \times 48' \times .0731 = 526.3 \text{ manhours}$$

(c) Plate Welding: (1st side) (Semi-automatic)

Weld 1 but 48' long @ 2030 manhours per foot.

$$3000 \div 2 \times 48' \times .2030 = 1461.6 \text{ manhours}$$

(d) Stiffener Fitting:

Fit 1800 5" x 4" x 1.8" stiffeners (15' long) @  
.0523 manhours per foot.

$$1800 \times 15' \times .0523 = 1412.1 \text{ manhours}$$

(e) Stiffener Welding: (Semi-automatic)

Weld 1800 5" x 4" x 1/8" stiffeners (2 sides) @  
.0438 manhours per foot.

$$1800 \times 15' \times 2 \text{ sides} \times .0438 = 2365.2 \text{ manhours}$$

(f) Turnover:

Turnover calculated @ .4 manhours

$$150 \times .4 = 60.0 \text{ manhours}$$

(g) Plate Gouging:

Gouge 1 butt 48' long @ .1155 manhours per foot.

$$150 \times 48' \times .1155 = 831.6 \text{ manhours}$$

(h) Plate Welding: (2nd Side) (Semi-automatic)

Weld 1 butt 48' long @ .1978 manhours per foot.

$$150 \times 48' \times .1978 = 1424.2 \text{ manhours}$$

(4) Material Handling:

- (a) Move 3007 1/2' x 48' x 5/8" plates to platen @  
5 min a move @ 5 plates per move.

$$300 \div 5 \times 5 \text{ min } 60 \text{ min } \times 3 \text{ men} = 15.0 \text{ manhours}$$

- (b) Move 300 7 1/2' x 48' x 5/8" plates to fitting  
p o s i t i o n .

$$300 \times 2 \text{ min a move } \times 60 \text{ min. } \times 3 \text{ men} \\ = 30.0 \text{ manhours}$$

- (c) Move 1800 stiffeners (15 @ time) to fitting area.

$$1800 \div 15 \times 5 \text{ min } \div 60 \text{ min } \times 3 \text{ men} = 30.0 \text{ manhours}$$

- (d) Move 1800 stiffeners to plate for fitting.

$$1800 \times 2 \text{ min } \div 60 \text{ min } \times 2 \text{ men} = 120.0 \text{ manhours}$$

- (e) Move 150 girders to welding area.

$$150 \times 10 \text{ min } \div 60 \text{ min } \times 3 \text{ men} = 75.0 \text{ manhours}$$

- (f) Move 150 girders for 2nd side welding.

$$150 \times 10 \text{ min } \div 60 \text{ min } \times 3 \text{ men} = 75.0 \text{ manhours}$$

- (g) Load 150 girders on flat bed for storage.

$$150 \times 15 \text{ min } \div 60 \text{ min } \times 3 \text{ men} = 113.0 \text{ manhours}$$

(5) Calculations Recap:

Operation	Manhours
Burning	240.0
Plate Fitting	526.3
Plate Welding	2885.8
Stiffener Fitting	1412.2
Stiffener Welding	2365.2
Turnover	60.0
Plate Gouging	831.6
Material Handling	458.0
Total	8,779.0

b. Series Production Process - Direct Labor Estimate

(1) Material Description:

150 girders 15' x 48' x 5/8" (2 plates 7 1/2' wide)  
1800 stiffeners 5" x 4" x 1/8" (15' long)

(2) Process:

(a) Burn girder plates on *3-axis* (4 plates simultaneous)

(b) Stiffeners to be purchased.

(c) Move girder plates to girder line (automated)

(d) Fit and tack plates

(e) 1st side butt weld

- (f) Fit and tack stiffeners
- (g) Weld stiffeners
- (h) Turnover
- (i) 2nd side welding and gouging
- (j) Load completed girder and store.

(3) Calculations:

(a) Burning:

Burn 300 plates (4 simultaneously) @ 1.6 hours  
x 2 *men*.

$$300 \div 4 \times 1.6 \times 2 = 240.0 \text{ manhours}$$

(b) Station No. 1 (Plate fitting and tacking)

$$1.5 \text{ hours per station} \times 3 \text{ men} = 4.5 \text{ manhours}$$

(c) Station No. 2 (1st side butt welding) Sub-arc

$$1.5 \text{ hours per station} \times 2 \text{ men} = 3.0 \text{ manhours}$$

(d) Station No. 3 (Stiffener fitting and tacking)

$$1.5 \text{ hours per station} \times 3 \text{ men} = 4.5 \text{ manhours}$$

(e) Station No. 4 (Stiffener welding) Sub-arc

1.5 hours per station x 4 men = 6.0 manhours

(f) Station No. 5 (Stiffener welding) Sub-arc

1.5 hours per station x 4 men = 6.0 manhours

(g) Station No. 6 (Gouging and 2nd side welding)

1.5 hours per station x 2 men = 3.0 manhours

(4) Material Handling:

(a) Move 300 7 1/2' x 48' x 5/8" plates to girder line  
@ 5 min a move @ 5 plates per *move*.

$300 \div 5 \times 5 \text{ min} \div 60 \text{ min} \times 3 \text{ men} = 15.0 \text{ manhours}$

(b) Move 300 7 1/2' x 48' x 5/8" plates to conveyor.  
system.

$300 \times .5 \text{ min} \times 3 \text{ men} = 7.5 \text{ manhours}$

(c) Move 150 girders to offload.

$150 \times 10 \text{ min} \div 60 \text{ min} \times 3 \text{ men} = 75.0 \text{ manhours}$

(d) *Move 1800 stiffeners to conveyor system.*

$1800 \div 15 \text{ per trip} \times 5 \text{ min a trip} \div 60 \text{ min} \times 3 \text{ men} = 30.0 \text{ manhours}$

(5) Calculations Recap:

Operation	Manhours
Burning	<i>,240.0</i>
Station No. 1	<i>675.0</i>
Station No. 2	<i>450.0</i>
Station No. 3	<i>675.0</i>
Station No. 4	<i>900.0</i>
Station No. 5	<i>900.0</i>
Station No. 6	<i>450.0</i>
Material Handling	<i>127.5</i>
Total	<i>4,417.5</i>

2.2.1 Description of Conveyor Line (See figure 2-1)

The conveyor line as developed utilizes 4 inch diameter schedule 40 pipe, fabricated into a series of rollers, with commercial bearings installed in each end of each roller assembly. The overall length of the line is 250 feet representing five in-line work stations with station No. 5 added alongside the last (No. 5) in-line station.

A plate storage bed is installed along side station No. 1 to minimize the delay caused by material shortages and to minimize the material handling time required to support the process.

At station No. 1 the first plate, which is 8'-0" wide by 48' - 0" long, is taken from the plate storage bed and located on the extreme far-side of the conveyor (upper side in figure 2- 1), against a built-in hard stop. The second plate is then taken from the storage bed, and butted against the first. Wedges are driven between the plates and a

topside back-up bar (which is removable) and the plates are tack-welded together. The two plates are then moved to station No. 2.

At station No. 2 the two plates are butt-welded together along the previously tacked seam utilizing the sub-arc process and then moved to station No. 3.

At station No. 3 a topside stiffener locating fixture, which is moveable across the width of the conveyor, is used to locate the stiffeners and secure them in place while they are each tacked in three places. Following the stiffener tacking the unit is moved to station No. 4.

At station No. 4 half of the stiffeners are welded to the plates after which the unit is moved to station No. 5.

At station No. 5 the second half of the stiffeners are welded to the plates and the unit is moved (laterally) to station No. 6 using an overhead bridge type crane which turns the panel over (stiffener side down) as it relocates the panel from station No. 5 to station No. 6.

At station No. 6 the original (stiffener side) seam weld which joined the two plates is back-gouged and welded. The floor or girder assembly is then offloaded to a transportation flatbed.

*NOTE:* Two stations are required to weld stiffeners in order to maintain line balance of processing time.

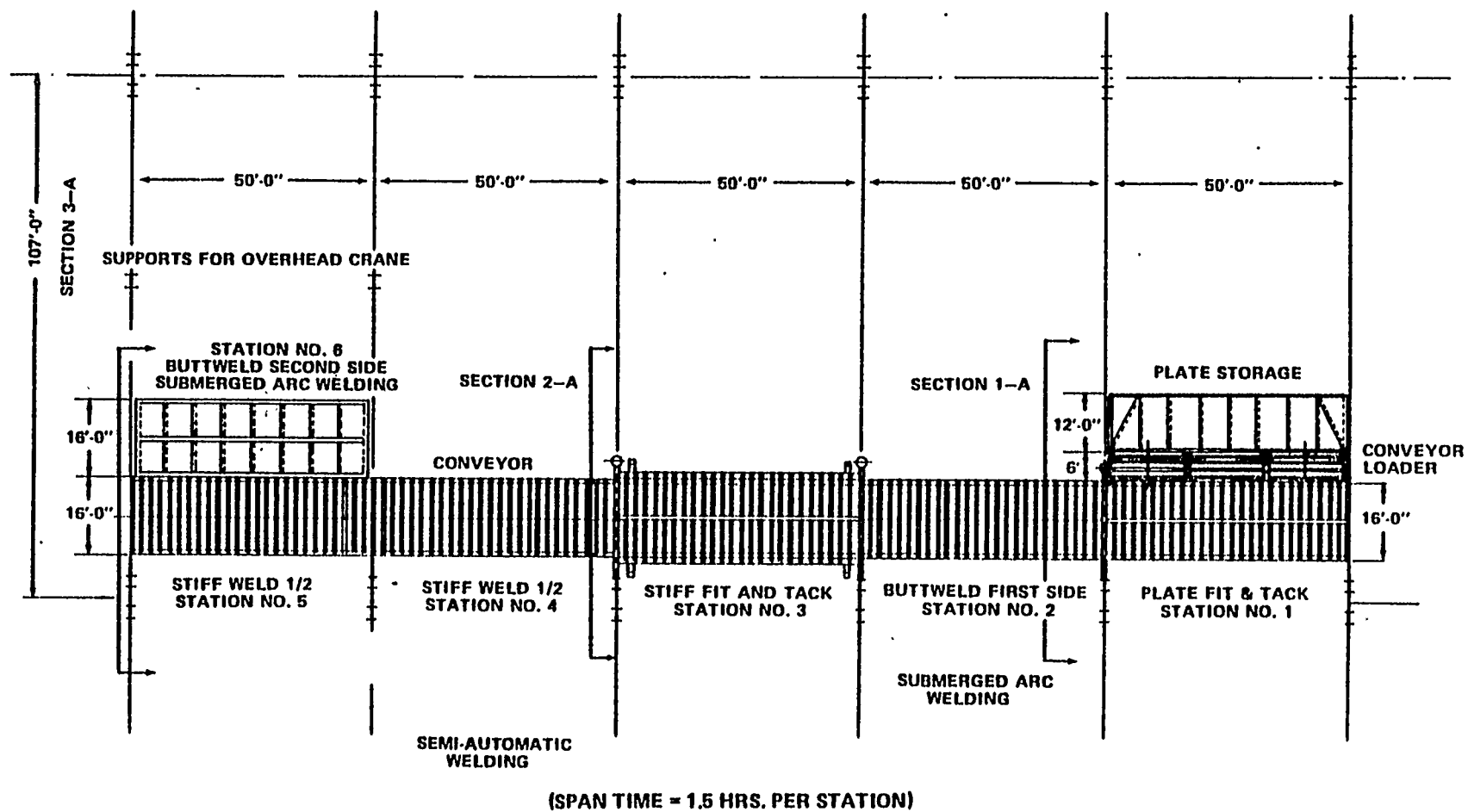


Figure 2-1. Floors and Girders, Automated Assembly Line

### 2.2.2 Cost of Conveyor Line

The actual cost of fabrication and installing the conveyor line was estimated, including the cost of the specialized equipment necessary for its operation.

The assumption was made that this installation would be correct in an existing building or shop, and that the proper utilities would be available to support the operation.

No attempt was made to estimate the cost of the welding equipment since the wide variety of equipment which is available and the related variances in cost would tend to dilute other information more pertinent to the study.

*Since* these factors could possibly present a significant additional cost in a specific application, it is recommended that they be considered in evaluating the study results.

The detailed cost estimate for fabrication and installation of the automated line is as follows:

#### a. Direct Labor:

##### (1) Fitting and Welding (Conveyor Frame)

##### 1 Combination

<i>Burner; Tacker</i>	x 5 days 2 shifts	= 80.0 m/hrs
4 Fitters	x 5 days 2 shifts	= 320.0 m/hrs
4 Welders	x 5 days 2 shifts	= 320.0 m/hrs
1 Operator	x 5 days 2 shifts	= 80.0 m/hrs
		800.0 m/hrs

(2) Fitting and Welding (Stiffener Jig )

1 Combination

Burner; Tacker	x 2 days 2 shifts	= 32.0 m/hrs
2 Fitters	x 2 days 2 shifts	= 64.0 m/hrs
1 Welder	X 2 days 2 shifts	= 32.0 m/hrs
		128.0 m/hrs

(3) Machinist to Install Rollers:

1 Welder	x 4 days 2 shifts	= 64.0 m/hrs
4 Machinists	x 4 days 2 shifts	= 256.0 m/hrs
1 Operator	x 4 days 2 shifts	= 64.0 m/hrs
		384.0 m/hrs

TOTAL DIRECT LABOR	1,312.0 m/hrs
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(4) Material Cost

1100 ft. 6" x 6" x 3/4" Angle	= \$ 3,867.00
2000 ft. 6" x 6" x 3/8" Angle	= \$ 3,651.00
300 ft. 8" x 8" x 15" Wide Flange	= \$ 551.00
2000 ft. 4" Dia. Schd. 40 Pip	= \$ 10,000.00
150 ft. 1 1/4" Round Bar	= \$ 77.00
100 ft. 4" x 1" Flat Bar	= \$ 167.00
	\$ 18,313.00

(5) Equipment Cost

(2)	2 H. P. Drive Motors including chain drive and sprockets	\$ 600.00
(250)	Bearings for conveyor rollers @ 3.00 each	\$ 750.00
(9)	Jib frames for welding lead supports @ 850.00 each	\$ 7,650.00
(1)	Overhead hoist crane for offloading girders	\$15,000.00
(1)	Power Pak for plate loading to conveyor	\$ 1,200.00
		\$25,200.00

(6) Calculations Summary

Total Material and Equipt. Cost	= \$43,513.00
Total Labor Cost (1, 312 m/hrs @ 12. 00/hr)	= \$15,744.00
Total Cost of Conveyor Line	= \$59,257.00

### 2.2.3 Floors and Girders - Cost Comparison

The cost comparison for the production of floors and girders for the first ship is summarized as follows:

SINGLE SHIP PRODUCTION	SERIES SHIP PRODUCTION
Special Tooling Cost = -0-	Tooling = \$59,257
Total Direct Labor = \$105,348 (8, 779 m/hrs @ \$12. 00/hr)	First Ship Production = \$53, 004 (5, 729 m/hrs @ \$12. 00)
First Ship Production	
Total First Ship Cost = \$105,348.00	Total First Ship Cost = \$112,261.00

The additional cost in the series production total represents a 6.670 additional cost over the cost of single ship type construction, for the first ship.

The “payback” or “break-even” point is realized on the second ship, with a 53% savings of direct labor being realized on each follow-on ship of the series.

Single Ship Production	Series Ship Production
First Ship Cost 105,348	112,267
Second Ship Cost 96,920	48,769
\$202,268	\$161,036

The cost comparison for ten shipsets of floors and girders is shown as follows:

SINGLE SHIP PRODUCTION			SERIES SHIP PRODUCTION	
Ships	Each Ship Cost	cum cost	Each ship cost	cum cost
Ship No. 1.	\$105,348	.\$105,348	\$112,267	\$112,267
*Ship No. 2	96,920	202,268	48,769	161, 036
Ship No. 3	92,306	294,574	46,447	207,483
Ship No. 4	89, 167	383,741	44,868	252,351
Ship No. 5	86,807	470,548	43,680	296,031
Ship No. 6	84,921	555,469	42,731	338,762
Ship No. 7	83,362	638,831	41,947	380,709
Ship No. 8	82,034	720,865	41, 278	421, 987
Ship No. 9	80, 876	801,741	40,696	462, 683
Ship No. 10	79,864	881,605	40, 187	502, 870
TOTALS	\$881,605		\$502,870	

\*Break-even point.

### 2.3 FABRICATION OF BRACKETS

The bracket selected for series production *is* essentially a gusset plate, 9'-0" x 9' -0", with a 1" face plate, 14'-0" long. (See figure 2-2).

In developing the series production manufacturing method, the conveyor line developed for the fabrication of the floors and girders was utilized in conjunction with a jig which locates the face plate against a stop and holds the web plate in place while the unit is being welded. (See figure 2-3).

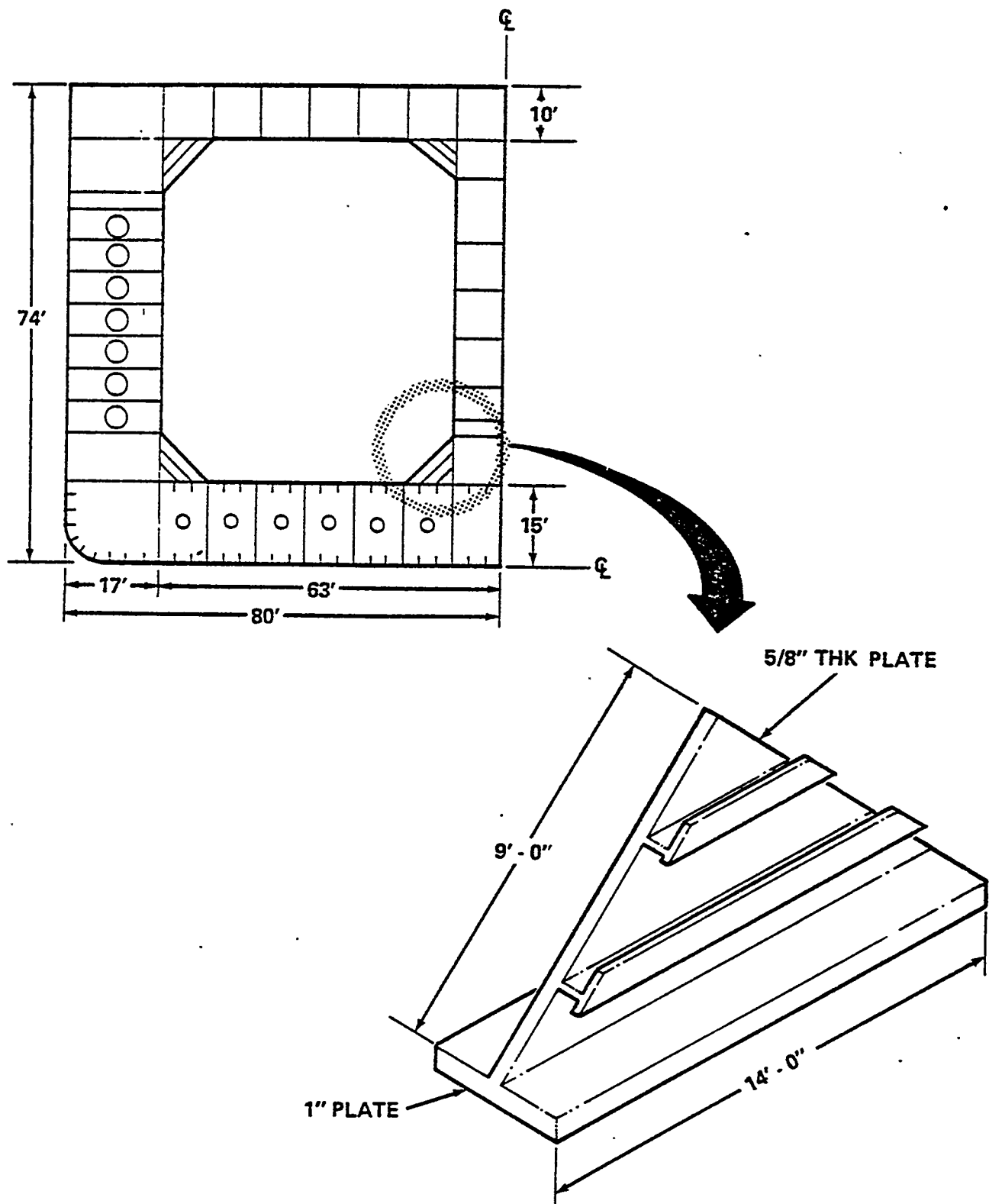


Figure 2-2. Bracket

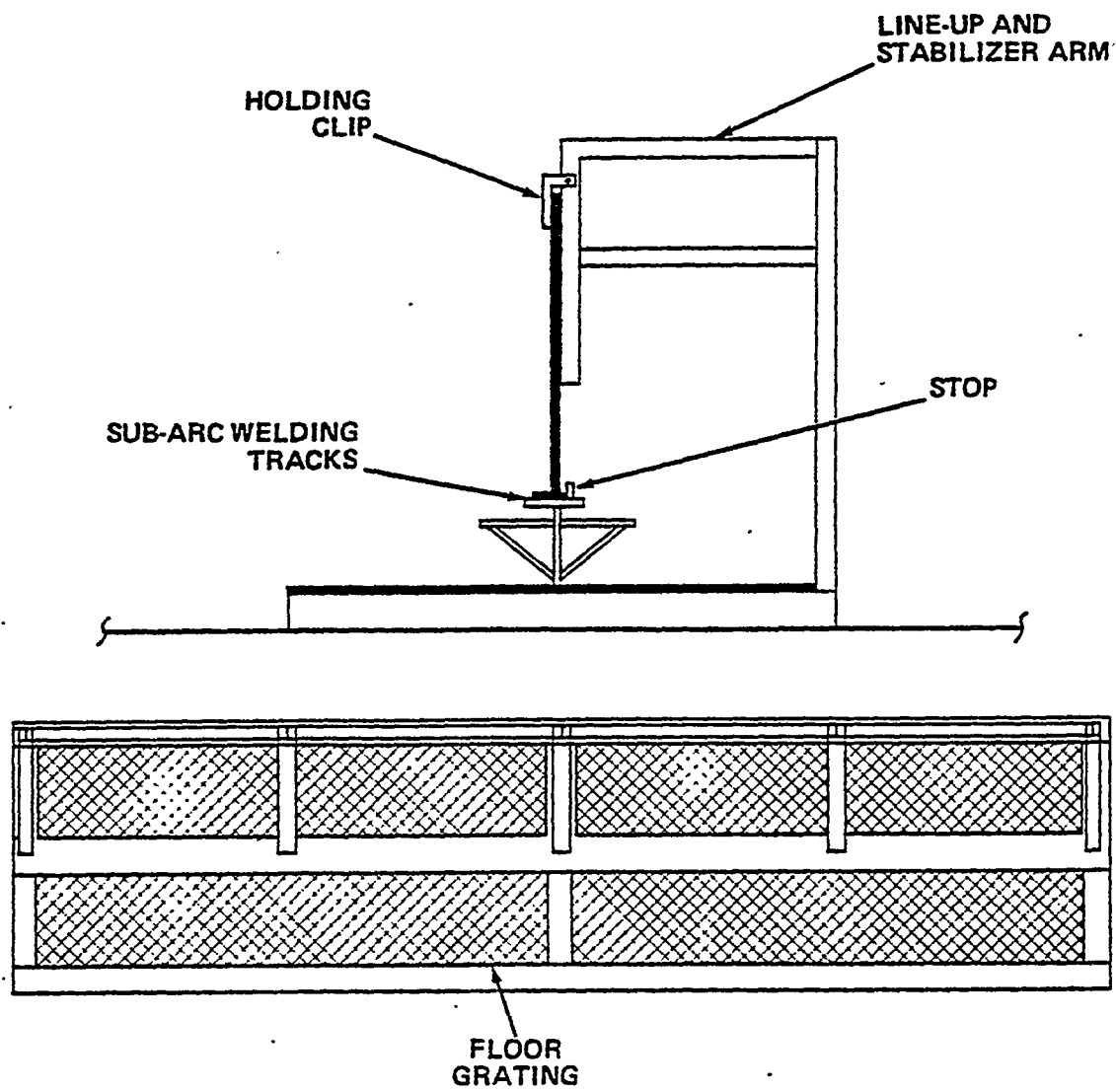


Figure 2-3. Bracket Holding Jig

Operation of the line is similar in concept to the operation described for floors and girders, except the dwell time is reduced to one hour at each station. (See figure 2-4. )

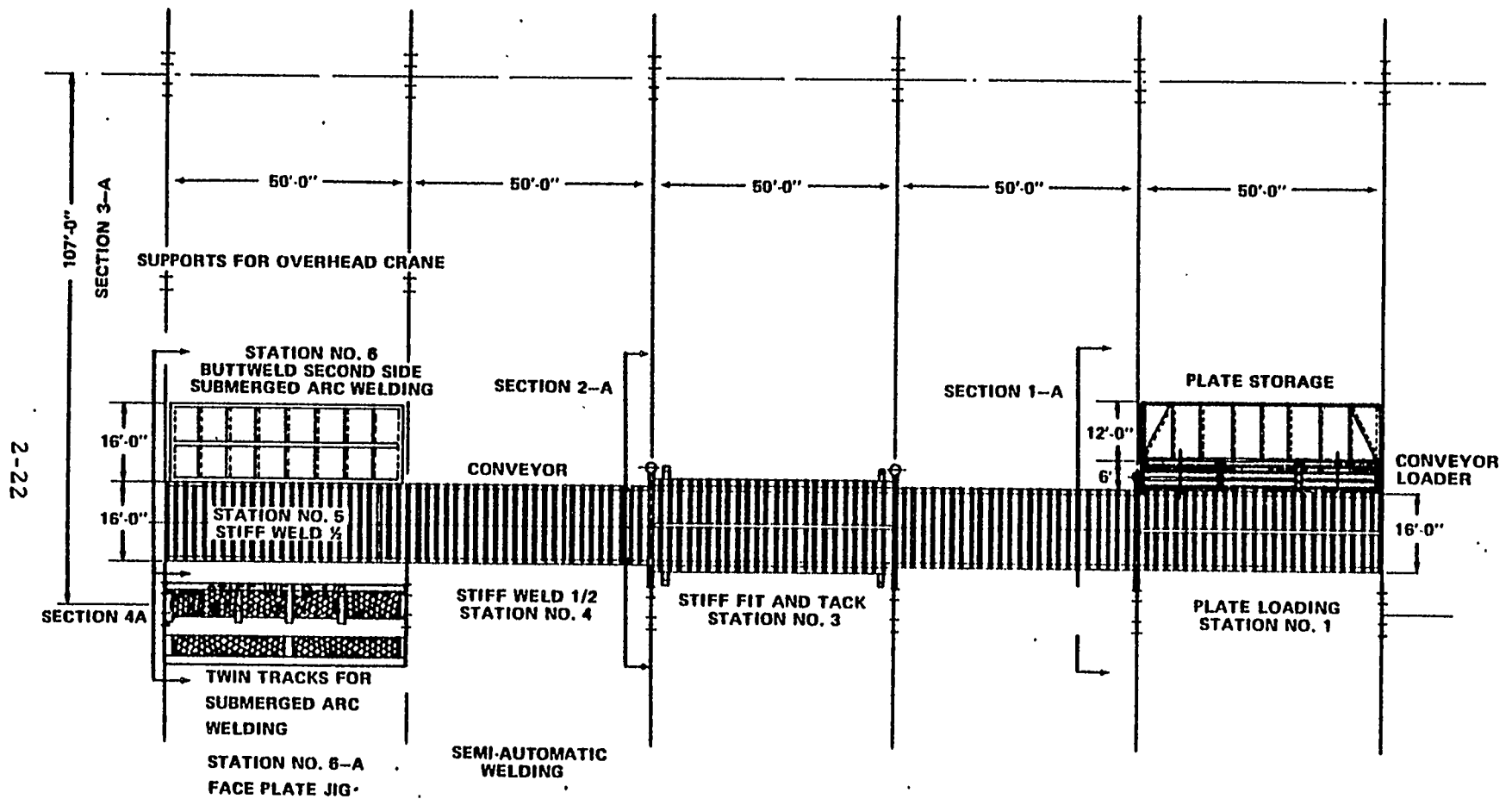
The estimate for the conventional fabrication sequence reflects the major pieces being burned *to* size in the fabrication ship, with final assembly being accomplished in a platen area.

The two estimates are as follows:

a. Single Ship Production of Brackets

(1) Process:

- (a) Burn bracket on 2:3-axis burner.
- (b) Burn flange plates on flame planer.
- (c) Stiffeners to be purchased.
- (d) Move material to platen area.
- (e) Fit stiffeners to bracket.
- (f) Weld stiffeners to bracket.
- (g) Fit and tack bracket to flange plate.
- (h) Weld bracket to flange plate.
- (i) Load completed bracket and store.



(SPAN TIME = 1.0 HR. PER STATION)

Figure 2-4. Structural Brackets Automated Assembly Line

(2) Calculations:

(a) Burning Brackets:

200 Brackets 9' x 9' x 13' x 7/8" (2 plates simultaneously) @1.6 hrs x 2 men.

$$200 \div 2 \times 1.6 \times 2 \text{ men} = 320.0 \text{ manhours}$$

(b) Burning Flange Plates:

Burn 200 flange plates 16" x 1" x 13' long @ (simultaneously) 1.14 hrs x 2 men.

$$200 \div 6 \times 1.14 \times 2 = 76.0 \text{ manhours}$$

(c) Stiffener Fitting:

Fit 200 stiffeners 5" X 4" X 1/8" (10') @ .0523 manhours per foot.

$$200 \times 10' \times .0523 = 104.6 \text{ manhours}$$

Fit 200 stiffeners 5" x 4" x 1/8" (6') @ .0523 manhours per foot.

$$200 \times 6' \times .0523 = 62.8 \text{ manhours}$$

(d) Stiffener Welding:

Weld 200 stiffeners 5" x 4" x 1/8" (10') @ .0438 manhours per foot.

$$200 \times 10 \times 2 \text{ sides} \times .0438 = 175.2 \text{ manhours}$$

Weld 200 stiffeners 5" x 4" x 1/8" (6') @ .0438

$$200 \times 6' \times 2 \text{ sides} \times .0438 = 105.1 \text{ manhours}$$

(e) Fit Brackets to Flanges:

Fit 200 brackets 9' x 9' x 13' x 5/8" to 1" x 16" x 13' flange @ .0678 manhours per foot.

$$200 \times 13' \times .0678 = 176.3 \text{ manhours}$$

(f) Weld Brackets to Flanges, 1st Side:

Weld 200 brackets 9' x 9' x 13' x 5/8" to 1" x 16" x 13' flange @ .2030 manhours per foot.

$$200 \times 13' \times .2030 = 527.8 \text{ manhours}$$

(g) Weld Brackets to Flanges, 2nd Side:

Weld 200 brackets 9' x 9' x 13' x 5/8" to 1" x 16" x 13' flanges @ .1978 manhours per foot.

$$200 \times 13' \times .1978 = 514.3 \text{ manhours}$$

(3) Material Handling:

- (a) Move 200 brackets from burn to platen @ 5 min.  
per move @ 5 brackets per move.

$$200 \div 5 \times 5 \text{ min} \div 60 \text{ min} \times 3 \text{ men} = 10.0 \text{ manhours}$$

- (b) Move 200 flanges from bum to platen @ 5 min  
per move @ 15 flanges per move.

$$200 \div 15 \times 5 \text{ min} \div 60 \times 3 \text{ men} = 3.3 \text{ manhours}$$

- (c) Move 400 stiffeners @ 5 min per move @ 15  
stiffeners per move.

$$400 \div 15 \times 5 \text{ min} \div 60 \times 3 \text{ men} = 6.67 \text{ manhours}$$

- (d) Move 400 stiffeners to fitting position @ 2 min  
per move.

$$400 \times 2 \text{ min} \div 60 \times 3 \text{ men} = 26.7 \text{ manhours}$$

- (e) Move 200 brackets and flanges to fitting position  
@ 10 min per move.

$$200 \times 10 \text{ min} \div 60 \times 3 \text{ men} = 100.0 \text{ manhours}$$

- (f) Load 200 completed brackets for storage @ 5 min 1  
each.

$$200 \times 5 \text{ min} \div 60 \text{ min} \times 3 \text{ men} = 50.0 \text{ manhours}$$

(4) Calculations Recap:

Operation	Manhours
Burning	396.0
Stiffener fitting	167.4
Stiffener welding	280.3
Bracket to flange fitting	176.3
Bracket to flange welding	1042.1
Material handling	216.7
I I TOTAL	2,278.8

b. Series Production of Brackets

(1) Material Description:

200 Brackets 9' x 9' x 13' x 7/8"  
200 Stiffeners 5" x 4" x 1/8" (10' long)  
200 Stiffeners 5" x 4" x 1/8" (6' long)  
200 Flanges 1" x 16" (13' long)

(2) Process:

- (a) Burn brackets on 2:3 axis-burner.
- (b) Burn flange plates on flame planer.
- (c) Stiffeners to be purchased.
- (d) Move material to automated bracket line.
- (e) Fit and tack stiffeners to bracket.

(f) Weld stiffeners to bracket.

(g) Fit, tack and weld flange to bracket in jib.

(h) Load completed bracket and store.

(3) Calculations:

(a) Burning Brackets:

200 brackets 9' x 9' x 13' x 7/8" (2 plates  
simultaneously) @ 1.6 hrs x 2 men.

$$200 \div 2 \times 1.6 \times 2 \text{ men} = 320.0 \text{ manhours}$$

(b) Burn Flange Plates:

Burn 200 flange plates 16" x 1" x 13' Long @  
(6 simultaneously) 1.14 hrs x 2 men.

$$200 \div 6 \times 1.14 \times 2 \text{ men} = 76.0 \text{ manhours}$$

(c) Station No. 1: (Plate fitting and tacking)

- 0 -

(d) Station No. 2: (1st side butt welding)

- 0 -

(e) Station No. 3: (Stiffener fitting and tacking)

$$1.0 \text{ hrs per station} \times 2 \text{ men} = 2.0 \text{ manhours}$$

(f) Station No. 4: (Stiffener welding)

$$1.0 \text{ hrs per station} \times 1 \text{ man} = 1.0 \text{ manhours}$$

(g) Station No. 5: (Stiffener welding)

$$1.0 \text{ hr per station} \times 1 \text{ man} = 1.0 \text{ manhours}$$

(h) Station No. 6-A: (Bracket to flange)

$$1.0 \text{ hr per station} \times 2 \text{ men} = 2.0 \text{ manhours}$$

(4) Material Handling:

(a) Move 200 brackets from flame planer to bracket line @ 5 min a move @ 5 brackets per move.

$$200 \div 5 \times 5 \text{ min} + 60 \text{ min} \times 3 \text{ men} = 10.0 \text{ manhours}$$

(b) Move 200 flanges from flame planer to bracket line @ 5 min per move @ 15 flanges per move.

$$200 \div 15 \times 5 \text{ min} + 60 \times 3 \text{ men} = 3.3 \text{ manhours}$$

(c) Move 200 brackets to conveyor system @ 5 min per move.

$$200 \div 5 \times 2 \text{ men} = 2.0 \text{ manhours}$$

(d) Move 200 brackets and flanges to jig for fitting and welding.

$$200 \times 2 \text{ min} + 60 \text{ min} \times 2 \text{ men} = 13.3 \text{ manhours}$$

(d) Move 200 completed brackets for offload.

(5) Calculations Recap: (200 @ 2 simultaneously)

Operation	Manhours <sup>1</sup>
Burning	396.0
Station No. 1	- 0 -
Station No. 2	- 0 -
Station No. 3	200.0
Station No. 4	100.0
Station No. 5	100.0
Station No. 6-A	200.0
Material Handling	61.9
TOTAL	1,057.9

Since the costs of fabricating and installing the conveyor line has already been amortized against the fabrication of the floors and girders, the cost will not be charged again to the fabrication of brackets.

The additional welding jig and the extension of the overhead bridge crane are new requirements, however, and these additional costs must be included in the final analysis for the fabrication of the brackets.

These additional costs *are* estimated as follows:

### a. Special Tooling and Equipment Costs

(1) Direct Labor:

(a) **Extend Overhead Crane Beams:**

## 1 Combination

Burner; Tacker      x 2 day 2 shifts =32.0

2 Fitters X 2 day 2 shifts = 64.0

1 Welder                      x 2 day 2 shifts =32.0

1 Operator x 2 day 2 shifts = 32.0

160.0 m

(b) Fitting and Welding (Jig):

## 1 Combination

Burner; Tacker      x 1 day 2 shifts = 16. O

2 Fitters x 1 day 2 shifts = 32.0

2 Welders x 1 day 2 shifts =32.0

1 Operator x 1 day 2 shifts = 16.0

96.0 m/

(c) Total Direct Labor	176.0 m/
------------------------	----------

(d) Total Direct Dollars

$$176.0 \times \$12.00/\text{Hr} = \$2112.00$$

(2) Material Costs:

310 ft. 12" x 10" x 53 lb tide flange	= \$2, 013.00
50 ft 30" x 15" x 172 lb wide flange	= \$1,054.00
600 sq. ft. 5/16" expanded floor grating	= \$1,912.00
150 ft 6" x 6" x 25 lb wide flange	= \$ 460.00
100 ft 3" x 3" x 5/16" angle	= \$ 112.00
<b>TOTAL MATERIAL COSTS</b>	<b>\$5,551.00</b>

(3) Equipment Costs:

(8) Jib Frames for welding lead supports @ 850.00 each	\$6,800.00
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(4) Calculations Summary

Labor Costs (Item (1)(d) above)	\$2112.00
Material Costs	5551.00
Equipment Costs	6800.00
<b>TOTAL COST</b>	<b>\$14,463.00</b>

### 2.3.2 Bracket Fabrication - Cost Comparison

The cost comparison for the production of brackets for the first ship is ,summarized as follows:

Single Ship Production		Series Ship Production	
Special Tool Cost = -O-		Tooling = 14,463	
First Ship Production		First Ship Production	
2,278 M/Hrs X 12.00 =		1058 M/Hrs X 12.00 =	
27,346		12,696	
TOTALS	\$27,346		\$27,159

The reader is reminded that the material, equipment and labor *costs* associated with the initial conveyor line installation is not included since these costs were absorbed by the series production of floors and girders.

The cost comparison for ten shipsets of brackets is as follows:

- Ships	Single Ship Production		Series Ship Production	
	Each Ship	c u m	Each Ship	c u m
Ship No. 1	\$27,346	\$27,346	\$27, 1.59	\$27, 159
Ship No. 2	25, 158	52, 504	11, 679	38, 838
Ship No. 3	23,961	76,465	11, 123	49,961
Ship No. 4	23, 146	99,611	10,745	60, 706
Ship No. 5	22,533	122, 144	10,461	71,167
Ship No. 6	22, 044	144, 188	10,233	81,400
Ship No. 7	.21,639	165,827	10, 045	91,445
Ship No. 8	21,294	187, 121	9,885	101,330
Ship No. 9	20,994	208, 115	9,746	110, 076
Ship No. 10	20,731	228,846	9,624	120,700

\*Pay- Back Point

## 2.4 FABRICATION OF SMALL PANELS

In developing the plan for the production of the small panels, the first choice was to build them on the same conveyor line as previously developed for the floors, girders and brackets.

However, preliminary efforts to develop a reasonable production schedule indicated that the first conveyor would be utilized to capacity, for production of floors, girders and brackets, and that it would, therefore, be necessary to develop a second "*line*" for the fabrication of the small panels.

Consideration was also given to mixing small panels with the larger panels contained in the next section, but this approach was rejected on the basis that the differences in size, work content and resultant "dwell" times would result in small panels "waiting" for larger panels which are downstream, with a subsequent loss of facility utilization.

It was, therefore, decided to set a size limitation for large and small panels, and separate the fabrication of panels which are in the 17' x 30' to 17' x 34' range from the fabrication of the larger 30' x 48' to 40' x 48' panels.

For the small panels a (new) conveyor line was developed, very similar in size to the one as previously described for the production of the floors, girders and brackets. (See figure 2-5. )

For the large panels, a separate "panel Shop" was developed, which will be described in the next section of the study.

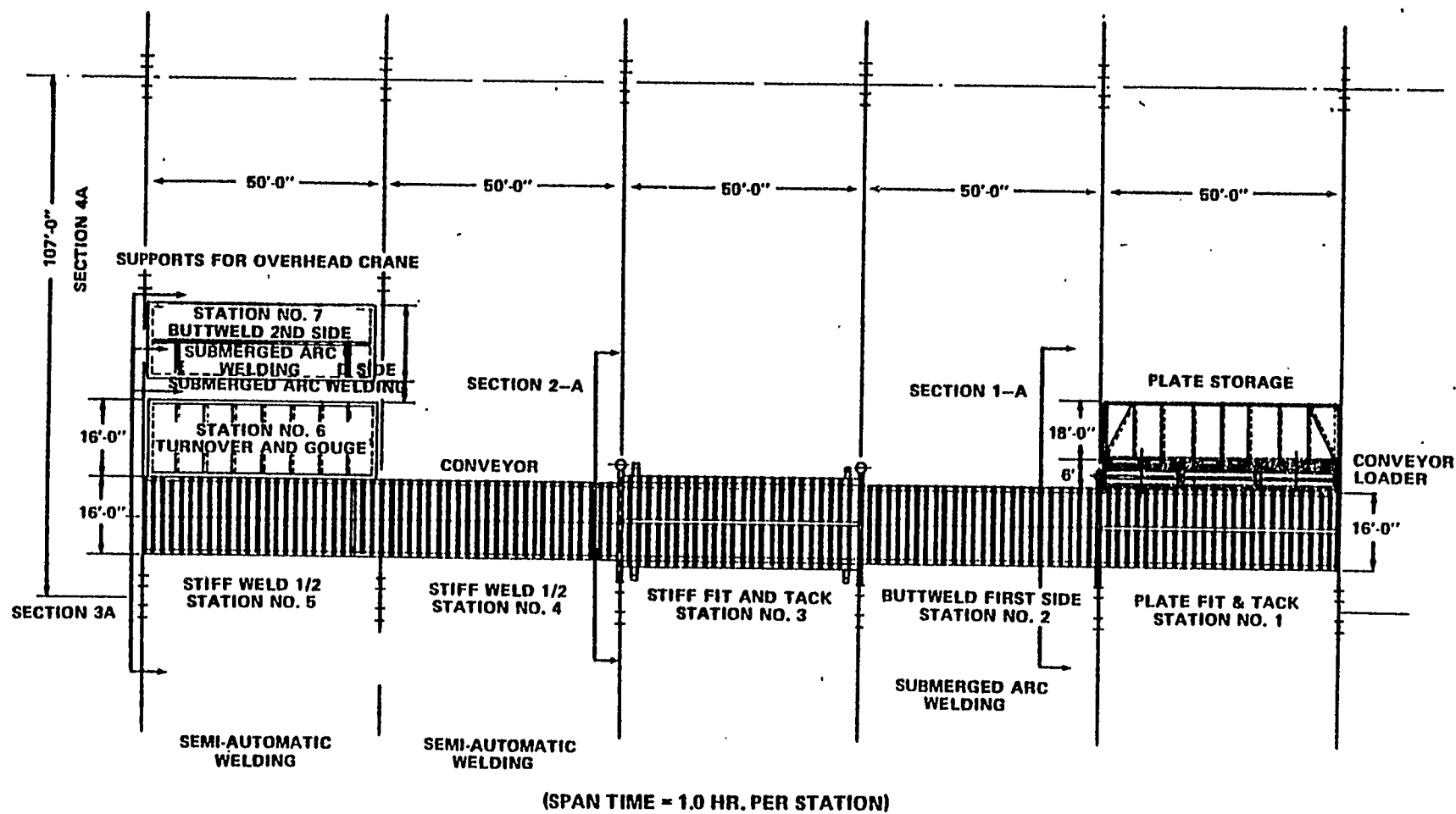


Figure 2-5. Small Panel, Automated Assembly Line

The basis for comparison, for small panels, was then established as follows:

1. Small panels for single- ship production would be assembled on *an* open platen, with piece parts cut to size in the fabrication shop.
2. Small panels for series - ship production would be assembled on an automated conveyor line, utilizing permanently installed stops to locate panels at a given station, and with piece parts cut to size in the fabrication shop.

Using these two alternate methods, estimates of the time required for fabrication of the small panels were derived as follows:

a. Small Panel - Single Ship Production

(1) Material Description:

62 panels 17' x 30' x 3/4" (average).  
62 panels 17' x 34' x 3/4" (average).  
434 stiffeners 5" x 4" x 1/8" x 30' long.  
558 stiffeners 5" x 4" x 1/8" x 34' long.

(2) Process:

- (a) Burn plates in fab shop.
- (b) Stiffeners to be purchased.
- (c) Move material to platen area.

(d) Fit and tack plates together.

(e) Butt weld 1st side (submerged arc).

(f) Turnover.

(g) Butt weld 2nd side (submerged arc).

(h) Layout, fit and tack stiffeners to panel.

(i) Gouge.

(j) Weld stiffeners to panel (submerged arc).

(k) Load completed panel and store.

(3) Calculations:

(a) Plate Burning:

434 plates 17' x 30' and 17' x 34' x 3/4"  
(2 plates simultaneously) @ 1.6 hrs x 2 men.

$$434 + 2 \times 1.6 \times 2 \text{ men} = 694.4 \text{ manhours}$$

(b) Plate Fitting and Tacking:

Fit 434 plates 17' x 30' and 17' x 34' x 3/4"  
@ .1211 manhours per foot.

$$5,270 \text{ lin ft} \times .1211 = 638.2 \text{ manhours}$$

(c) Butt Weld, 1st Side:

Weld 1st side, 434 plates 17' x 30' and 17' x 34' x 3/4" @ .2536 manhours per foot.

$$5,270 \text{ lin ft} \times .2536 = 1,336.5 \text{ manhours}$$

(d) Gouging:

$$5,270 \text{ lin ft} \times .1155 = 608.7 \text{ manhours}$$

(e) Butt Weld, 2nd Side:

Butt weld 2nd side, 434 plates, 17' x 30' and 17' x 34' x 3/4" @ .1740 manhours per foot.

$$5,270 \text{ Lin ft} \times .1740 = 917.0 \text{ manhours}$$

(f) Fit and Tack Stiffeners:

Fit 992 stiffeners 5" x 4" x 1/8" x 17' long @ .0523 manhours per foot.

$$16,864 \text{ lin ft} \times .0523 = 882.0 \text{ manhours}$$

(g) Weld Stiffeners to Panel:

Weld 992 stiffeners 5" x 4" x 1/8" x 17' long @ .0438 manhours per foot.

$$16,864 \text{ Lin ft} \times 2 \text{ sides} \times .0438 = 1477.3 \text{ manhours}$$

(4) Material Handling:

- (a) Move 434 plates from 2:3 axis burner to platen area @ 5 min per move @ 5 plates per move.

$$434 \div 5 \times 5 \text{ min} + 60 \text{ min} \times 3 \text{ men} = 21.7 \text{ manhours}$$

- (b) Move 992 stiffeners @ 5 min a move @ 15 stiffeners per move.

$$992 \div 15 \times 5 \text{ min} + 60 \text{ min} \times 3 \text{ men} = 16.5 \text{ manhours}$$

- (c) Move 434 plates to fitting position @ 5 min per plate.

$$434 \times 5 \text{ min} + 60 \text{ min} \times 3 \text{ men} = 108.5 \text{ manhours}$$

- (d) Move 992 stiffeners to fitting position @ 2 min per stiffener.

$$992 \times 2 \text{ min} + 60 \text{ min} \times 2 \text{ men} = 66.1 \text{ manhours}$$

- (e) Turnover 124 panels @ 10 min per panel.

$$124 \times 10 \text{ min} + 60 \text{ min} \times 3 \text{ men} = 62.0 \text{ manhours}$$

- (f) Load 124 completed panels for storage @ 10 min per move.

$$124 \times 10 \text{ min} + 60 \text{ min} \times 3 \text{ men} = 62.0 \text{ manhours}$$

(5) Calculations Recap:

Operation	Manhours
Burning	694.4
Plate Fitting	638.2
Gouge	608.7
Butt Welding	2253.5
Stiffener Fitting	882.0
Stiffener Welding	1477.3
Material Handling	336.8
TOTAL	6890.9

b. Small Panels - Series Production:

(1) Material Description:

62 panels 17' x 30' x 3/4" (average)  
62 panels 17' x 34' x 3/4" (average)  
434 stiffeners 5" x 4" x 1/8" x 30' long  
558 stiffeners 5" x 4" x 1/8" x 34' long

(2) Process:

- (a) Burn plates in fab shop.
- (b) Stiffeners to be purchased.
- (c) Move material *to conveyor* line.
- (d) Fit and tack plates together.

(e) 1st side welding.

(f) *Gouging*.

(g) 2nd side welding.

(h) Load completed panel and store. .

(3) Calculations:

(a) Plate Burning:

434 plates 17' x 30' and 17' x 34' .x 3/4" (2 plates simultaneously) @ 1.6 hrs x 2 men.

$$434 \div 2 \times 1.6 \times 2 \text{ men} = 694.4 \text{ manhours}$$

(b) Station No. 1: (Plate fitting and tacking)

$$1.0 \text{ hr per station} \times 3 \text{ men} = 3.0 \text{ manhours}$$

(c) Station No. 2 (1st side butt welding)

$$1.0 \text{ hr per sta} \times 2 \text{ men} = 2.0 \text{ manhours}$$

(d) Station No. 3: (Stiffener fitting and tacking)

$$1.0 \text{ hr per station} \times 3 \text{ men} = 3.0 \text{ manhours}$$

(e) Station No. 4: (Stiffener welding)

$$1.0 \text{ hr per station} \times 4 \text{ men} = 4.0 \text{ manhours}$$

(f) Station No. 5: (Stiffener welding)

$$1.0 \text{ hr per station} \times 4 \text{ men} = 4.0 \text{ manhours}$$

(g) Station No. 6: (Turnover & Gouge)

$$1.0 \text{ hr per station} \times 1 \text{ man} = 1.0 \text{ manhours .}$$

(h) Station No. 7: (Butt welding 2nd side)

$$1.0 \text{ hr per station} \times 2 \text{ men} = 2.0 \text{ manhours}$$

(4) Material Handling:

(a) Move 434 plates from 2:3 axis burner to conveyor line @ 5 min per move @ 5 plates per move.

$$434 \div 5 \times 5 \text{ min} \div 60 \text{ min} \times 3 \text{ men} = 21.7 \text{ manhours}$$

(b) Move 992 stiffeners to conveyor line @ 5 min per move @ 15 stiffeners per move.

$$992 \div 15 \times 5 \text{ min} \div 60 \text{ min} \times 3 \text{ men} = 16.5 \text{ manhours}$$

(c) Turnover 124 panels @ 5 min per panel.

$$124 \times 5 \text{ min} \div 60 \text{ min} \times 3 \text{ men} = 31.0 \text{ manhours}$$

(d) Load 124 completed panels for storage @ 5 min per move.

$$124 \times 5 \text{ min} \div 60 \text{ min} \times 3 \text{ men} = 31.0 \text{ manhours}$$

(5) Calculations Recap:

Operation	Manhours
Burning	694.4
Station No. 1	372.0
Station No. 2	248.0
Station No. 3	372.0
Station No. 4	496.0
Station No. 5	496.0
Station No. 6	124.0
Station No. 7	1 0 0 . 2
TOTAL	3, 150.6

2.4.1 Description of Conveyor Line

The operation *of* the conveyor line for the fabrication of the small panels is essentially the same as the operation required for floors and girders, with the addition of station No. 7, which makes the final “backside” weld of the panel seam.

The requirement for this additional station is generated by the dwell time of (1) hour, which has been fixed for all other stations on the line. Backgouge and weld of the small panels could not be accomplished within this span time, and the added station was, therefore, required. (See figure 2-5. )

a. Direct Labor:

(1) Fitting and Welding (Conveyor Frame):

1 Combination

Burner; Tacker	x 5 days 2 shifts =	80.0 m/hrs
4 Fitters	x 5 days 2 shifts =	320.0 m/hrs
4 Welders	x 5 days 2 shifts =	320.0 m/hrs
1 Operator	x 5 days 2 shifts =	80.0 m/hrs
		800.0 m/hrs

(2) Fitting and Welding (Stiffener Jig):

1 Combination

Burner; Tacker	x 2 days 2 shifts =	32.0 m/hrs
2 F i t t e r s	x 2 days 2 shifts =	65.0 m/hrs
1 W e l d e r	x 2 days 2 shifts =	32.0 m/hrs
		128.0 m/hrs

(3) Machinist to Install Rollers:

1 Welder	X 4 days 2 shifts =	64.0 m/hrs
4 Machinists	x 4 days 2 shifts =	256.0 m/hrs
i Operator	x 4 days 2 shifts =	64.0 m/hrs
		384.0 m/hrs

(4) Total Direct Labor (1) + (2) ÷ (3) = 1,312.0 m/hrs

(5) Total Direct Labor Dollars \$15,744.00

1,312 m/Hrs x \$12. 00/Hr = \$15,744

(6) Material Cost:

1200 ft 6" X 6" x 3/4" angle	= \$ 4,218.00
2100 ft 6" X 6" x 3/8" angle	= \$ 3,834.00
350 ft 8" x8" X 15 lb wide F l a n g e	= \$ 643.00
2100 ft 4" dia. schd. 40 pipe	= \$10,500.00
200ft 1 /4" round bar	= \$ 103.00
125 ft 4" x 1" flat bar	= \$ 209.00
 TOTAL MATERIAL COST	 \$19,507.00.

(7) Equipment Cost:

(2)	2 H. P. drive motors including chain drive and sprockets	\$ 600.00
(275)	Bearings for conveyor rollers @ 3.00 each	\$ 825.00
(9)	Jib frames for welding lead supports	\$ 7,650.00
(1)	Overhead hoist crane for offloading and turnover	\$15,000.00
(1)	Power pak for plate loading to conveyor	\$ 1,200.00
	Total Equipment Cost	\$25,275.00

(8) Calculations Summary:

9

Total Labor Cost	\$15,744.00
Total Material Cost	\$19,507.00
Total Equipment Cost	\$25,275.00
Total Cost of Conveyor Line	\$60,526.00

2.4.2 Small Panels - Cost Comparison

The cost comparison for the production of small panels for the first ship is summarized as follows:

Single Ship Production	Series Ship Production
Special Tooling Cost -O-	Special Tooling Cost 60, 524.00
First Ship Production 82, 690.00	First Ship Production 37,800.00
(6, 890 m/hrs x 12. 00)	(3, 150 m/hrs x 12. 00)
Total First Ship Cost =	Total First Ship Cost =
\$82,690.00	\$98,326.00

Establishment of the conveyor line is not considered to be cost effective for single ship production, as can be seen by the higher total cost of the series production method.

The cost comparison for ten shipsets of small panels is as follows :

Single Ship Production			Series Ship Production	
Ship	Each Ship	c u m I	E a c h S h i p I	C u m
Ship No. 1	\$82,691.00	\$ 82,691.00	\$98,333.00	\$ 98,333.00
*Ship No. 2	76,076.00	158,767.00	37, 681.00	136,014.00
Ship No. 3	72,454.00	231,221.00	35,887.00	171,901.00
Ship No. 4	65,990.00	301,211.00	34,666.00	206,567.00
Ship No. 5	68, 137.00	369,348.00	33,749.00	240,316.00
Ship No. 6	66,657.00	436, 005.00	33,016.00	273,332.00
Ship No. 7	65,433.00	501,438.00	32,410.00	305,742.00
Ship No. 8	64,391.00	565,829.00	31,894.00	337,636.00
Ship No. 9	63,482.00	629,311.00	31,443.00	369,079.00
Ship No. 10	62,688.00	691,999.00	31,050.00	400, 129.00
TOTALS	1\$691,999.00		\$400,129.00	

\*Pay- Back Point.

## 2.5 FABRICATION OF LARGE PANELS

In developing the manufacturing plan for the fabrication of large panels, the total ship requirement was established for a 150, 000 DW.T tanker, 920' long and 160' in beam.

By combining the requirement for flat bottom shell plates, flat side- shell plates, decks, bulkheads and tank-tops, a total requirement of (280) large flat panels was established for each ship.

This requirement was judged to represent a substantial amount of the total steel fabrication requirement, and the establishment of a separate facility to be used exclusively for the fabrication of *large* panel assemblies, was considered to be justifiable at least from a preliminary standpoint, for series production.

For single- ship production, the large panel assemblies are planned for assembly on an open platen, with piece parts being cut to size and large stiffeners being fabricated in the fabrication shop.

The two estimates, reflecting these two different approaches, are as follows:

a. Large Panel Line - Single Ship Production

(1) Material Description

(a) Bottom Shell:

(20) panels 30' x 48' x 1"

(20) panels 40' x 48' x 1"

(b) Side Shell:

(20) panels 30' x 48' x 3/4" avg.

(20) panels 34' x 48' x 3/4" avg.

(c) Decks:

(40) panels 40' x 48' x 7/8" avg.

(d) Bulkheads:

(60) -panels 30' x 48' x 5/8" avg.

(60) panels 29' x 48' x 5/8" avg.

(e) Tank Top:

(20) panels 33' X 48' x 5/8" avg.

(20) panels 30' x 48' x 5/8" avg.

(f) Stiffeners:

(320) bottom shell stiffeners 24" x 9" x 7/16" (B. U.

(140) side shell stiffeners 16" x 7" x 3/16" (B. U.S.

(280) side shell stiffeners 18" x 8 3/4" x 3/16"  
(B. U.S. )

(360) Deck Tees 8" x 5/6" (purchased)

(90) Bhd stiffeners 14 3/8" x 6 7/16" x 7/16"  
(B. U.S. )

(180) Bhd stiffeners 14 3/8" x 9 5/8" x 11/16"  
(B. U.S. ) -

(180) Bhd stiffeners 24 3/8" x 8 9/16" x 11/16"  
(B. U.S.)

(90) Bhd stiffeners 24 3/8" x 8 1/4" x 3/4" (B.U.S

(2) Process:

(a) Burn plates on flame planers.

(b) Strip plates for T-beam welder.

(c) Move plates to platen area.

(d) Move stiffeners to platen area.

- (e) Layout, fit and tack plates.
- (f) Weld 1st side.
- (g) Turnover and backgouge.
- (h) Weld 2nd side.
- (i) Layout, fit and tack stiffeners.
- (j) Weld stiffeners to panel.
- (k) Layout, fit and tack web frames.
- (l) Weld web frames.
- (m) Load completed panel and store.

(3) Calculations:

(a) Plate Burning:

Burn 940 plates on flame planer @ 2 plates  
simultaneously @ 1.6 hrs x 2 men.

$$940 \div 2 \times 1.6 \times 2 \text{ men} = 1504:0 \text{ manhours}$$

(b) Stripping for T-Beam Welder:

Strip 2,920 pieces @ 6 pieces simultaneously @  
1.69 hrs x 2 men.

$$2,920 \div 6 \times 1.69 \times 2 \text{ men} = 1645.0 \text{ manhours}$$

(c) T-Beam Welding:

$$1460 \text{ stiffeners} \times 48' = 70,080 \text{ lin ft.}$$

$$70,080 \text{ lin ft} \times 12 \text{ inches} = 840,960 \text{ inches}$$

$$\text{Welding Speed} = 18 \text{ I. P. M.}$$

$$840,960 \div 18 \text{ I. P.M.} \div 60 \text{ min} \times 2 \text{ men} = 1557.3 \text{ manhours}$$

(d) Plate Layout, Fit and Tack

Fit 1" plate to same. 100 butts 48' long @ .1829 manhours per foot.

$$100 \times 48 \times .1829 = 877.9 \text{ manhours}$$

Fit 3/4" plate to same. 100 butts 48' long @ .121, manhours per foot.

$$100 \times 48 \times .1211 = 581.3 \text{ manhours}$$

Fit 7/8" plate to same. 120 butts 48' long @ 1.57

$$120 \times 48 \times .1572 = 905.5 \text{ manhours}$$

Fit 5/8" plate to same. 340 butts 48' long @ .090 manhours per foot.

$$340 \times 48 \times .0901 = 1470.4 \text{ manhours}$$

**(e) Plate Welding, 1st Side:**

**Weld 5/8" x 9/16" submerged arc. 100 butts 48' long @ .2809 manhours per foot.**

$$100 \times 48 \times .2809 = 1348.3 \text{ manhours .}$$

**Weld 1/2" x 9/16" submerged arc. 100 butts 48' long @ .2524 manhours per foot.**

$$100 \times 48 \times .2524 = 1,211.5 \text{ manhours}$$

**Weld 7/16" x 9/16" submerged arc. 120 butts 48' long @ .2369 manhours per foot.**

$$120 \times 48 \times .2369 = 1,364.5 \text{ manhours}$$

**Weld 3/8" x 1/2" submerged arc. 340 butts 48' long @ .2030 manhours per foot.**

$$340 \times 48 \times .2030 = 3,313.0 \text{ manhours}$$

**(f) Plate Gouging:**

**Gouge 660 butts 48' long @ . 1155 manhours per foot.**

$$660 \times 48 \times .1155 = 3,659.0 \text{ manhours}$$

**(g) Plate Welding, 2nd Side:**

**Weld 1/2" x 1/2" submerged arc. 100 butts 48' long @ .2320 manhours per foot.**

$$100 \times 48 \times .2320 = 1,113.6 \text{ manhours}$$

**Weld 1/2" x 7/16" submerged arc. 100 butts 48' long @ .2030 manhours per foot.**

$$100 \times 48 \times .2030 = 974.4 \text{ manhours}$$

**Weld 7/16" x 3/8" submerged arc. 120 butts 48' long @ .1616 manhours per foot.**

$$120 \times 48 \times .1616 = 930.8 \text{ manhours}$$

**Weld 3/8" x 5/16" submerged arc. 340 butts 48' long @ .1234 manhours per foot**

$$340 \times 48 \times .1234 = 2,014.9 \text{ manhours}$$

**(h) Stiffener Layout, Fitting and Tacking:**

**Fit 24" x 9" x 3/4" (avg. ) to panel.**

$$590 \text{ stiffeners} \times 48' \text{ long} = 28,320 \text{ lin ft @ } .1318 \text{ manhours per foot} = 3,732.6 \text{ manhours}$$

**Fit 16" x 7" x 3/16" to panel**

$$140 \text{ stiffeners} \times 48' \text{ long} = 6,720 \text{ lin ft @ } .0884 \text{ manhours per foot} = 594.0 \text{ manhours}$$

**Fit 18" x 8 3/4" x 3/16" and 16 3/8" x 8 1/8" x 7/8" to panel.**

**460 stiffeners x 48' long = 22, 080 lin ft @  
. 1057 manhours per foot = 2, 333.9 manhours**

**Fit 8" x 5/ 16': purchased tee to panel.**

**360 stiffeners x48 long = 17,280 Lin ft @  
. 0660 manhours per foot = 1, 140.5 manhours**

**Fit 14 3/8" x 6 7/16" x 7/16" and 14 3/8" x 9 5/8" x 11/16" to panel.**

**270 stiffeners x 48' long = 12, 960 Lin ft @  
.0978 manhours per foot = 1, 267.5 manhours**

**(i) Stiffener Welding:**

**Weld 1 /2' fillet to panel - submerged arc.**

**955 stiffeners x 48' long = 45,840 Lin ft of  
weld @ .1539 manhours per foot =  
7, 054 manhours**

**Weld 3/16" fillet to panel - submerged arc.**

**370 stiffeners x 48' long = 17, 760 lin ft of  
weld @ .0438 manhours per foot =  
777.9 manhours**

**Weld 1 /4" fillet to panel - submerged arc.**

**360 stiffeners x 48' long = 17,280 lin ft of  
weld @ .0504 manhours per foot =  
870.9 manhours**

**Weld 5/16" fillet to panel - submerged arc.**

**135 stiffeners x 48' long = 6,480 lin ft of  
weld @ .0652 manhours per foot =  
422.5 manhours**

**(j) Layout, Fit and Tack Webb Frames:**

**Fit 9'x 30' x 3/4" webb frames to panel.**

**40 webb frames x 30' long = 1200 lin ft of  
fit @ .1782 manhours per foot =  
213.8 manhours**

**Fit 9' x 29' x 3/4" webb frames to panel.**

**40 webb frames x 29' long = 1160 lin ft of  
fit @ .1782 manhours per foot =  
206.7 manhours**

**(k) Weld Webb Frames to Panel:**

**Weld 9' x 30' x 3/4" webb frames to panel.**

**40 webb frames x 30' long = 1200 lin ft of  
weld @ .3078 manhours per foot =  
369.4 manhours**

**Weld 9' x 29' x 3/4" webb frames to panel.**

**40 webb frames x 29' Long = 1160 lin ft of  
weld @ .3078 manhours per foot =  
357.1 manhours**

**(4) Material Handling:**

**(a) Move 940 plates from burners to large panel line  
@ 5 min per move @ 5 plages per move.**

**940+5 x 5min+60minx3 men =  
47.0 manhours**

**(b) Move 1,820 stiffeners to large panel line @ 5 min  
@ 15 stiffeners per move.**

**1820+ 15x5min+60 minx 3 men=  
30.3 manhours**

**(c) Move 2,920 stiffener components to tee beam  
welder @ 5 min per move @ 30 pieces per move.**

**2,290 + 30 x 5 min+60 min x 3 men=  
24.3 manhours**

**(d) Move 940 plates from platen storage to fitting  
posit ion @ 5 min per move.**

**940 x 5 min+ 60 min x 3 men = 235.0 manhours**

**(e) Move 1,820 stiffeners to fitting position @ 2 min per stiffener.**

$$1,820 \times 2 \text{ min} + 60 \text{ min} \times 3 \text{ men} = 121.3 \text{ manhours}$$

**(f) Turnover 280 panels @ 10 min per panel.**

$$280 \times 10 \text{ min} + 60 \text{ min} \times 3 \text{ men} = 140.0 \text{ manhours}$$

**(g) Load 280 panels for storage @ 10 min per move.**

$$280 \times 10 \text{ min} + 60 \text{ min} \times 3 \text{ men} = 140.0 \text{ manhours}$$

**(5) Calculations Recap:**

<b>Operation</b>	<b>Manhours</b>
<b>Plate Burning</b>	<b>1504.0</b>
<b>Stripping for Tee- Beam</b>	<b>1645.0</b>
<b>Tee- Beam Welding</b>	<b>1557.3</b>
<b>Plate Layout, Fit and Tack</b>	<b>3835.1</b>
<b>Plate Welding 1st Side</b>	<b>7237.3</b>
<b>Plate Gouging</b>	<b>3659.0</b>
<b>Plate Welding 2nd Side</b>	<b>5032.7</b>
<b>Stiffener Layout and Fit</b>	<b>9068.5</b>
<b>Stiffener Welding</b>	<b>9126.1</b>
<b>Layout and Fit Webb Frames</b>	<b>420.5</b>
<b>Weld Webb Frames</b>	<b>726.5</b>
<b>Material Handling</b>	<b>737.9</b>
<b>TOTAL</b>	<b>44, 549.9</b>

**b. Large Panel Line - Series Production**

**(1) Material Description:**

**(a) Bottom Shell:**

**(20) panels 30' x 48' x 1"**

**(20) panels 40' x 48' x 1"**

**(b) Side Shell:**

**(20) panels 30' x 48' x 3/4" avg.**

**(20) panels 34' x 48' x 3/4" avg.**

**(c) Decks:**

**(40) panels 40' x 48' x 7/8" avg.**

**(d) Bulkheads:**

**(60) panels 30' x 48' x 5/8" avg.**

**(60) panels 29' x 48' x 5/8" avg.**

**(e) Tank Top:**

**(20) panels 33' x 48' x 5/8" avg.**

**(20) panels 30' x 48' x 5/8" avg.**

**(f) Stiffeners:**

**(320) bottom shell stiffeners 24" x 9" x 7/16"  
(B. U.S.)**

**(140) side shell stiffeners 16" x 7" x 161 (B'UB. U.S.**

**(240) side shell stiffeners 18" x 8 3/4" x 3/16"**  
**(B. U.S.)**

**(360) deck tees 8" x 5/16" (purchased)**

**(90) Bhd stiffeners 14 3/8" x 6 7/16" x 7/16"**  
**(B. U.S. )**

**(180) Bhd stiffeners 14 3/8" x 9 5/8" x 11/16"**

**(180) Bhd stiffeners 16 3/8" x 8 1/8" x 7/8" (B. U. )**

**(180) Bhd stiffeners 24 3/8" x 8 9/16" x 11/16"**  
**(B. U.S. )**

**(90) Bhd stiffeners 24 3/8" x 8 1/4" x 3/4" (B. U. )**

**(a) Process:**

**(a) Burn plates on flame planers.**

**(b) Strip plate for tee beam welder.**

**(c) Move plates to large panel line.**

**(d) Move stiffeners to large panel line.**

**(e) Layout, fit and tack plates**

**(f) Weld 1st side.**

**(g) Turnover.**

**(h) Backgouge and weld 2nd side.**

**(i) Stiffener layout, fit and weld.**

**(j) Layout, fit and tack webb frames.**

**(k) Weld webb frames**

**(1) Load completed panel and store.**

**(3) Calculations:**

**(a) Plate Burning:**

**Burn 940 plates on flame planer @ 2 plates  
simultaneously @ 1.6 hrs x 2 men.**

$$940 \div 2 \times 1.6 \times 2 \text{ men} = 1504.0 \text{ manhours}$$

**(b) Stripping for T-Beam Welder:**

**Strip 2,920 pieces @ 6 peices simultaneously @  
1.69 hrs x 2 men.**

$$2,920 \div 6 \times 1.69 \times 2 \text{ men} = 1645.0 \text{ manhours}$$

**(c) T-beam Welder:**

$$1460 \text{ stiffeners} \times 48' = 70,080 \text{ lin ft.}$$

$$70,080 \text{ Lin ft} \times 12 \text{ inches} = 840,960 \text{ inches}$$

$$\text{Welding speed} = 18 \text{ I.P. M.}$$

$$840,960 \div 18 \text{ I. P.M.} \div 60 \text{ min} \times 2 \text{ men} = 1557.3 \text{ manhours}$$

**(d) Station No. 1: (Plate fitting and tacking)**

**2.5 hrs per station x 280 panels x 3 men.**

**2.5 x 280 x 3 men = 2, 100 manhours**

**(e) Station No. 2: (1st side welding)**

**2.5 hrs per station x 280 panels x 2 men.**

**2.5 x 280 x 2 men = 1400 manhours**

**(f) Station No. 3: (Turnover)**

**See Material Handling for required manhours.**

**(g) Station No. 4: (Backgouge and 2nd side welding)**

**2.5 hrs per station x 280 panels x 3 men**

**2.5 x 280 x 3 men = 2,100 manhours**

**(h) Station No. 5: (Stiffener layout)**

**2.5 hrs per station x 280 panels x 2 men.**

**2.5 x 280 x 2 men = 1,400 manhours**

**(i) Station No. 6: (Fit, layout and weld 1/2 stiffeners)**

**2.5 hrs per station x 280 panels x 3 men.**

**2.5 x 280 x 3 men = 2, 100 manhours**

**(j) Station No. 7: (Fit, layout and weld 1/2 stiffeners )**

**2.5 hrs per station x 280 panels x 3 men.**

$$2.5 \times 280 \times 3 \text{ men} = 2,100 \text{ manhours}$$

**(k) Station No. 8: (Fit transverse members for lifting)**

**2.5 hrs per station x 280 panels x 3 men.**

$$2.5 \times 280 \times 3 \text{ men} = 2,100 \text{ manhours}$$

**(4) Material Handling:**

**(a) Move 940 plates from burners to large panel line  
@ 5 min per move @ 5 plates per move.**

$$940 \div 5 \times 5 \text{ min} + 60 \text{ min} \times 3 \text{ men} = 47.0 \text{ manhours}$$

**(b) Move 1,820 stiffeners to large panel line @ 5 min  
per move @ 15 stiffeners per move.**

$$1,820 \div 15 \times 5 \text{ min} + 60 \text{ min} \times 3 \text{ men} = 30.3 \text{ manhours}$$

**(c) Move 2,920 stiffener components to tee-beam welder  
@ 5 min per move @ 30 pieces per move.**

$$2,920 \div 30 \times 5 \text{ min} + 60 \text{ min} \times 3 \text{ men} = 24.3 \text{ manhours}$$

**(d) Move 940 plates from large panel line rack to fitting position @ 3 min per move.**

$$940 \times 3 \text{ min} + 60 \text{ min} \times 2 \text{ men} = 94.0 \text{ manhours}$$

**(e) Turnover 280 panels at station No. 3 @ 10 min per panel x 3 men = 280 x 10 min.+ 60 min x 3 men = 140.0 manhours**

**(f) Load 280 panels for storage @ 10 min per move.**

$$280 \times 10 \text{ min} + 60 \text{ min} \times 3 \text{ men} = 140.0 \text{ manhours}$$

**(5) Calculations Recap:**

<b>Operation</b>	<b>Manhours</b>
<b>Plate Burning</b>	<b>1504.0</b>
<b>Tee- Beam Stripper</b>	<b>1645.0</b>
<b>Tee- Beam Welding</b>	<b>1557.3</b>
<b>Station No. 1</b>	<b>2100.0</b>
<b>Station No. 2</b>	<b>1400.0</b>
<b>Station No. 3</b>	<b>- o -</b>
<b>Station No. 4</b>	<b>2100.0</b>
<b>Station No. 5</b>	<b>1400.0</b>
<b>Station No. 6</b>	<b>2100.0</b>
<b>Station No. 7</b>	<b>2100.0</b>
<b>Station No. 8</b>	<b>2100.0</b>
<b>Material Handling</b>	<b>475.6</b>
<b>TOTAL</b>	<b>18,481.9</b>

## **2. 5.1 Description of Equipment Included in Panel Shop (See figure 2-6)**

**The major items required for the establishment of the large panel line are described as follows:**

### **Conveyor System**

**Roll- chain type with hydraulic lifting devices at each station. Four rows of conveyors are required, approximately 400 feet long, for the movement of panel assemblies through the shop.**

### **20- Ton-Magnet Crane**

**Required to lift incoming plate from flatbed and position plate at station No. 1.**

### **80- Ton Bridge Crane**

**Required at turnover station No. 3, to turn panel assembly which has been butt-welded on one side only.**

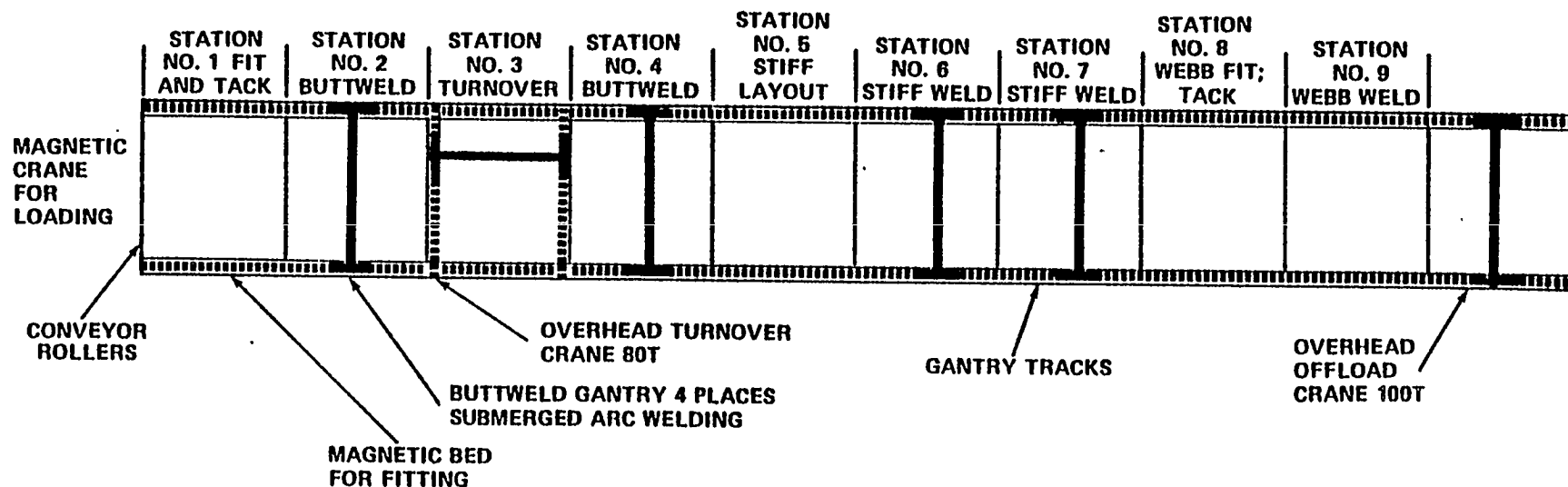
**Note: Implementation of one - sided welding would eliminate this requirement.**

### **100-Ton Bridge Crane**

**Required to lift completed assemblies as required for loading on transportation type vehicle.**

**(4) Twin Arc Fillet Gentries - (2) Required to accomplish butt-welding at stations No. 2 and No. 4, and (2) required to weld stiffeners to panel assembly at stations No. 6 and No. 7.**

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(SPAN TIME = 2.5 HRS. PER STATION)

## **Building**

**Steel structure with sheet metal siding and roof. Three levels of internal height clearance as follows:**

<b>Stations No. 1 and No. 2</b>	<b>- 40' - 0"</b>
<b>Station No. 3</b>	<b>- 80' - 0"</b>
<b>Stations No. 4 thru No. 9</b>	<b>- 50' - 0"</b>

**Concrete floor, with reinforcement in way of major equipment locations and as required to support column loadings purchased by overhead cranes. Over-all size 90' wide by 500' long.**

## **Omissions**

- 1. Manual Welding Equipment**
- 2. Facilities - restrooms, office space, etc.**
- 3. Utilities - Welding gases, compressed air, etc.**
- 4. Auxiliary equipment - material handling, etc.**

## **Cost Estimate:**

<b>1. Conveyor System</b>	<b>1,500,000</b>
<b>2. 20 Ton Magnetic Crane</b>	<b>225, 000</b>
<b>3. 80 Ton Bridge Crane</b>	<b>200,000</b>
<b>4. 100 Ton Bridge Crane</b>	<b>3 5 0 , 0 0 0</b>

5.	(4) Twin Arc Welding Gantries	2,000, 000
6.	Building, Complete	2,250,000
	<b>TOTAL COST</b>	<b>\$ 6 , 5 2 5 , 0 0 0</b>

## **2. 5.2 Description of Panel Shop Operation**

Sized plates will arrive at the end of the Panel Shop. The plates will be picked up by a 20-ton magnetic bridge crane and placed on the end of the first work station on the panel line, where the plates will be aligned and the seams faired and tack welded.

At the second work station on the panel assembly line, the seams and butts in the plates will be welded on the first side using submerged arc welding equipment.

The panels will be turned over at the third work station by an 80-ton bridge crane and the second side of the panel will be back gouged and submerged arc welded at the fourth work station.

After completion of the plate seams and butt welds, the stiffener locations on the panels will be laid out manually at the fifth work station.

The sixth and seventh work stations will be outfitted with an automatic twin arc gantry to weld stiffeners to the panel. The stiffeners could be fed to the twin arc machine by a conveyor, but this feature is not included in this estimate.

The eighth work station has been provided so that the stiffeners can be welded manually if either of the twin arc machines malfunctions and to allow for the fitting of the larger web frames.

The panels will be completed at work station nine, where the web frames, brackets, etc. , are manually welded.

The completed panels will be removed from the panel assembly line by a 100-ton bridge crane and placed on stands so that they can be picked up by a hydraulic jack-up bed transporter.

The proposed Panel Shop, although not as highly automated as the current status of the art, has been designed to provide the required productive capability while minimizing capital expenditures.

The building would be constructed of steel frame, pile supported concrete footings, metal roof and siding, metal sash, skylights, concrete floor and pile supported concrete foundations for heavy equipment and high load bearing equipment.

## 2. 5.3 Cost Comparison - Large Panel Fabrication

The cost comparison for the production of large panel assemblies for the first ship is summarized as follows:

	Single Ship	Series Ship Production
<b>Tooling &amp; Facility Cost</b>	-0-	<b>\$6,525,000</b>
<b>First Ship Production Labor</b> (44, 550 m/hrs x 12. 00)	<b>\$534,600</b>	<b>\$ 221,784</b> (18, 482 m/hrs x 12. 00)
<b>TOTALS</b>	<b>\$534,600</b>	<b>\$6,764,784</b>

The cost comparison for ten shipsets of panel assemblies is shown as follows:

Ship No.	single Ship Production		Series Ship Production	
	Each Ship Cost	cum cost	Each Ship Cost	cum cost
1	534,600	534, 600	6,746,784	6,746,784
2	491,831	1,026,431	204,041	6,950,825
3	468,416	1,494,847	194, 327	7,145,152
4	452,484	1,947,331	187, 718	7,332,870
5	440,509	2,387,840	182, 750	7,515,620
6	430,940	2,818,780	178, 780	7,694,400
7	423,028	3,241,808	175,498	7,869,898
8	416,292	3,658, 100	172, 703	8,042, 601
9	410,411	4,068, 511	170,264	8,212,865
10	405,279	4,473,790	168, 134	8,380,999
	4,473.790		8,380,999	

As can be seen, the payback point has not been reached within the ten shipsets, due to the significant investment required to establish the large panel line. While the reduced direct labor costs of the panels fabricated in the shop represent a significant savings, the initial cost of the facility can only be justified over a long period of time, and must be considered a long-term investment.

## 2.6 SUMMARY AND CONCLUSIONS

With the exception of the Large Panel portion of the study, the manufacturing costs as developed for each of the ship components were significantly reduced by the application of series production methods.

**In each case, the cost of special tooling was justifiable on a (2) ship construction basis, with savings for follow- on ships resulting in a continually expanding cost differential.**

**By combining the separate categories for a given number of ships, the total savings accumulated for the construction of a given number of ships can be determined. The combined savings for a (3) and (4) ship contract are summarized as follows:**

### **3-Ship Contract**

	<b>Floors</b>	<b>Girders</b>	<b>Brackets</b>	<b>Small Panels</b>	<b>Total</b>
<b>Single</b>	<b>294,574</b>	<b>294,574</b>	<b>76,465</b>	<b>231,221</b>	<b>896,834</b>
<b>Series</b>	<b>207,483</b>	<b>207,483</b>	<b>49,961</b>	<b>171,901</b>	<b>636,828</b>
<b>3-ship savings =</b>					<b>.\$260,006</b>

### **4-Ship Contract**

	<b>Floors</b>	<b>Girders</b>	<b>Brackets</b>	<b>Small Panels</b>	<b>Total</b>
<b>Single</b>	<b>383,741</b>	<b>383,741</b>	<b>99,611</b>	<b>301,211</b>	<b>1,168,304</b>
<b>Series</b>	<b>252,351</b>	<b>252,351</b>	<b>60,706</b>	<b>206,567</b>	<b>771,975</b>
<b>4-ship savings =</b>					<b>\$396,329</b>

**Since the savings indicated are substantial for even a “limited” series production contract, the techniques employed would appear to be highly desirable and worthy of series consideration for adaptation to existing or anticipated production contracts.**

With the special tooling costs amortised on the first (3) or (4) ship contract, the same equipment can be adapted to suit a follow-on contract, and the elimination of the tooling costs would result in projected savings as follows:

**3-Ship Contract (ships 4, 5, 6)**

	<b>Floors</b>	<b>Girders</b>	<b>Brackets</b>	<b>Small Panels</b>	<b>Total</b>
<b>Single</b>	<b>260,895</b>	<b>260,895</b>	<b>67,723</b>	<b>204,784</b>	<b>794,297</b>
<b>Series</b>	<b>131,279</b>	<b>131,279</b>	<b>31,439</b>	<b>101,431</b>	<b>395,428</b>
<b>3-ship savings =</b>					<b>\$398,869</b>

**4-Ship Contract (ships 4-7)**

	<b>Floors</b>	<b>Girders</b>	<b>Brackets</b>	<b>Panels</b>	<b>Total</b>
<b>Single</b>	<b>344,257</b>	<b>344,257</b>	<b>89,362</b>	<b>270,217</b>	<b>1,048,093</b>
<b>Series</b>	<b>173,226</b>	<b>173,226</b>	<b>41,484</b>	<b>133,841</b>	<b>521,777</b>
<b>4-ship savings =</b>					<b>\$526,316</b>

While a certain amount of modification may be required to adapt the conveyor set-ups to the new requirements, the cost for accomplish this task is viewed as minimal and insignificant in comparison to the projected savings.

Similar savings would then be realized on all future contracts which could utilize the specialized set-ups already established

**In reviewing the large panel fabrication study, it should be noted that while the difference in direct labor costs is greater (when comparing single-ship to series-ship production) in this area than for any of the other items reviewed, the substantial capital investment required to establish the Panel Shop can only be justified on a long-term basis, and not as required to suit the immediate needs of a single ship or limited series production contract.**

**Here then, is an example of an area which can be adapted to continuous future use, but which can only be established as a part of a long-range planning effort aimed at the expansion of series production techniques within the shipyard.**

**VOLUME III**  
**PART 3**  
**WORK STATIONS**

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**VOLUME III**  
**PART 6**  
**WORK STATIONS**

**3.1 INTRODUCTION**

The "work station" concept as applied to a manufacturing process is defined as follows: Specific geographical locations within a facility, identified by an alpha/numeric designator, at which pre-planned operations are accomplished repetitively to an exacting pre-established time schedule (See table 6.1 - Example of Work Station Numbering System ).

The purpose of this part of the study is to examine the work station process as it is currently being used in non-marine and marine industries. Data that is gathered and developed from this examination will be evaluated to determine the feasibility of utilizing work stations in series production of ships.

**3.2 NON-MARINE INDUSTRIES**

The following non-marine industries were visited by representatives of the study group during the data gathering phase of the study.

- a. **Westinghouse Air and Brake (WABCO )**  
**Peoria, Illinois**
- b. **General Motors (Coach and Truck)**  
**Pontiac, Michigan**
- c. **The Boeing Company**  
**Seattle, Washington**

Table 3-1. Example of List of Work Stations

Work Station	Description
WS-001	Plate issue from steel yard
WS-002	Shape issue from steel yard
WS-003	Flame planer No. 2, CM-100 - burning machine
WS-004	CM-70 Burning machine (1/10 scale & tape)
WS-006	Burning machines CM-60 No. 1, CM-60 No. 2, CM-56
WS-008	Burning machines - flame planer
WS-009	Angle/beam welder
WS-010	Burning machines - flame planer (mfg'd shapes)
WS-016	Web frame assembly area - (shop)
WS-019	Bulldozer (plate shop)
WS-020	Furnace (plate shop)
WS-021	Press "C" (plate shop)
WS-022	Brake (plate shop)
WS-023	Inside rolls (plate shop)
WS-024	Outside rolls (plate shop)
WS-025	Platen rolls (at south end of raised slab)
WS-026	Shop assembly (platen support)
WS-027	Platen operations (sub-assembly)
WS-029	Platen stock storage
WS-031	Machinist storage - ways No. 2
WS-032	Machinist's pre-erection outfitting
WS-033	Mangle rolls - (blacksmith shop)
WS-036	Shop assembly (erection & outfitting support)
WS-037	Small parts profiling (plate shop)
WS-042	Kit operation (staging)
WS-043	Weld-out area (plate shop)
WS-046	Innerbottom floor assy area (plate shop)
WS-049	Ways & pre-erection outfitting storage
WS-050	Pre-erection outfitting
WS-055	Sandblasting & paint
WS-069	Yard in-process inventory (east of area a)
WS-072	Plt shop pre-fab: steel plate (& plate C/F)
WS-073	Plt shop pre-fab: yard mfg'd AB, MT, IB
WS-074	Plt shop pre-fab: structural AN, TB, IB, WF
WS-075	Plate shop pre-fab: round bar (& C/F)
WS-076	Plt shop pre-fab: square bar, hex bar, tubing
WS-077	Plt shop pre-fab: pipe (& C/F)
WS-078	Plt shop pre-fab: channel (& C/F)
WS-079	Plt shop pre-fab: aluminum (& C/F)
WS-080	Alum. receipt & alum. cuttings (plate shop)
WS-081	Identify at R-5 off-loading for staging
WS-082	Plate receipt & plt cut-from (plate shop)
WS-083	Shape receipt (plate shop)
WS-084	Punch press (plate shop)

**Table 3-1. Example of List of Work Stations (Continued)**

<b>Work Station</b>	<b>Description</b>
WS-085	Band saw (plate shop)
WS-086	Plate cuttings (plate shop)
WS-087	Shape cuttings (plate shop)
WS-088	Flat bar receipt & F.B. cut-from (plate shop)
WS-089	Flat bar cuttings (plate shop)
WS-090	Platen pre-fab information & instructions
WS-092	Receipt of fabricated stock into steel yard
WS-093	Issue of yard mfg'd parts and/or assy's
WS-096	Layout info & instrs. for prefab operations
WS-101	Warehouse issue of material
WS-102	Pipe issue (pipe yard)
WS-106	Pipe annex (small pipe)
WS-108	Pantograph, (pipe shop)
WS-109	Pipe fabrication area (pipe shop bldg No. 4)
WS-112	Ship board installation - shipfitters T/C 12
WS-120	Pipe pre-erection outfitting area
WS-121	Shipboard install. outside machinists T/C 21
WS-130	Shipboard installation - pipefitters T/C 30
WS-150	Shipboard install. sheetmetal fitters T/C 50
WS-151	Shipboard installation - riggers, T/C 51
WS-157	Shipboard installation carpenters (joiners)
WS-170	Shipboard installation - electricians T/C 70
WS-200	Machine shop assembly
WS-206	Bore & ream operations - machine shop
WS-207	Machine and/or fabricate per drawing details
WS-306	Casting for bronze material - foundry
WS-360	Galvanize (bldg No. 9)
WS-406	Electric shop (building No. 6)
WS-505	Small parts manufacture - sheet metal shop
WS-506	Ventilation duct M/O & fab. sheet metal shop
WS-507	Heavy gauge mark-out & fab. sheet metal shop
WS-511	Kitting area - sheet metal shop
WS-515	Shear: (for angle & F.B.) - sheet metal shop
WS-518	Material issue - sheet metal shop
WS-525	Sheet metal shop purchase from - N/C stock
WS-606	Rigging loft assembly
WS-706	Label plate shop
WS-707	Carpenter shop fab area at repair yard
WS-708	N/C carpenter shop
WS-906	Electrical parts storage
WS-909	Outfitting machinist office
WS-910	Compartment installation
WS-911	Module or unit assembly
WS-912	Erection

**d. General Electric (Gas Turbines )  
Evandale, Ohio**

**e. General Electric (R. R. Locomotives)  
Erie, Pennsylvania**

**3.2.1 Westinghouse Air and Brake**

This company produces large trucks for off-the-road use.

**a. Average weight is 175,000 lb.**

**b. The annual output is 350 to 400 vehicles**

**c. The facility processes approximately 20,000 tons of steel p  
year with 1800 employees.**

**d. The facility is completely stationized. Until two years ago, the production line consisted of a moving conveyor, through all stations. Each production unit was assembled in sequer with each unit dependent upon completion of the precedin-g u prior to a "line" move. Frequent line stoppages occured du to material shortages and late delivery of parts for a partic lar model. The lack of flexibility with this method of prodn tion was considered unacceptable.**

**Within the past two years the production line has been modified . follows :**

**a. Additional work stations (referred to as "stalls") have been established along the existing conveyer.**

- b. The “stalls” are manned and equipped to assemble any one of the current models of trucks.
- c. The conveyer is used primarily to deliver the basic component parts and sub-assemblies to the stalls.
- d. If a parts shortage exists on a particular model, the work effort is concentrated on models for which parts are available.
- e. When the shortage has been alleviated work is resumed on that model until the original schedule has been *recovered*.
- f. In conjunction with the work station modification the production manager is now allowed to make certain deviations from the established model schedule, if a production advantage is to be gained. The restriction is that all models scheduled within a time frame must be completed by the end date.

**Prerequisites for production of a new model in this particular work station concept are:**

- a. A complete engineering design
- b. An operational unit, road tested, changes made as required.
- c. All changes incorporated into finished drawings.
- d. Complete pre-planning for each work station.

### **3.2.2 General Motors (Coach & Truck)**

**This facility produces light to medium heavy trucks and buses.**

- a. There are 400 models and types produced.
- b. The annual production rate is 100,000 units.
- c. There are 18, 000 employees on the work force.

**This facility is stationized, with 100 percent powered conveyers, geared to constant motion. The main production line is fed by auxiliary conveyer lines and the assembly process is fixed in-line sequencing of models with no allowance for deviation or flexibility. To preclude work stoppages due to parts shortages, extensive safeguard measures have been incorporated, for example:**

- a. A minimum of 30 days supply of parts is maintained.**
- b. Special expediting trucks make daily deliveries from nearby sources.**
- c. Cargo aircraft are available for quick delivery of spare parts from distant suppliers, if the need arises.**

**Each work station is manned for 100 percent operation, plus 20 percent to allow for personnel replacement and to accomplish on-line-repairs to defective parts, if possible. A unit that cannot be repaired on-line is carried through to completion and dispositioned at the completion station. The production line is not stopped during the production run except for extreme emergency.**

**The prerequisites for this type of work station concept are:**

- a. A finished design and manufacture of an operational unit.**
- b. Extensive pre-planning to piece-part level of detail.**
- c. A test assembly run in a pilot plant to perfect the assembly process.**

- d. A computerized material control system and *cross* reference capability to assure that all parts are available to support a given production run, and to maintain an adequate material source.

### **3.2.3 Boeing Aircraft**

The facility visited was the Renton Division and is, as all other facilities visited, primarily an assembly plant. There was very little evidence of detail and/or minor sub-assembly work accomplished here. The end product is very large commercial air craft (over 300,000 lb).

The entire facility is stationized, but not in the conveyed production line concept. The work stations are more of the geographic location set-up, and in each work station the various parts and components required to make a complete major assembly (or module) of the aircraft is assembled, i. e. , fuselage (or sections thereof), wings, center sections, empennage, etc. The major assemblies (modules ) are completed in the various work stations and then moved to the mating station (erection area) where the assemblies are joined to form the completed aircraft. The method of movement from station to station varies with the type and size of the assembly--bridge crane, wheeled dolly, or airlift device. (Ref. Part 8 of this study).

The prerequisites for production are:

- a. A market survey to predict requirements and anticipate potential sales (Commercial contracts ).
- b. A manufacturing plan. This is the key document for the beginning of a new model. The development of this plan starts

**two years prior to production and one year prior to engineering. The total effort requires 20 men, steady state, for two years.**

- c. An extensive pre-planning effort by the Industrial Engineering Department is exerted to establish and assign operations to work stations, identify and order special, jigs and fixtures, and establish production schedules.**
- d. Concurrently with initial design a full scale mockup is constructed. This verifies symmetry and form, allows system and component installation, verification of system routing, eliminates interferences of component installation and in passenger aircraft a test of environmental control systems. The production control and planning departments use the completed mockup to verify the accuracy of installation sequence on work orders, and the bills of material.**
- e. A flying test unit and a prototype model are usually built concurrently. As the flying test unit is in the stages of final installation, the prototype structural unit is static tested to determine ultimate strength.**
- f. If during the initial test flights, no current or latent defect in structure or performance is detected, the production process that has been pre-planned, tooled and set up in work stations is rapidly accelerated to full schedule.**

**Note: The events (pre-requisites ), leading to the full production process run in many cases concurrently. Some production effort and work station pre -planning are started 3 months after engineering (design).**

#### **3.2.4 General Electric (Gas Turbines )**

**The product is the LM2500 aircraft derivative gas turbine engine that has been adapted for marine use. The unit weight is 11, 300 lb.**

**The facility is completely stationized and makes extensive use of jigs and fixtures. The assembly jigs are wheel mounted and serve as dollies for moving from station to station.**

**All parts and materials are pre-planned and kitted by work station requirement and are delivered to the in-line work stations on a scheduled basis. The workers and installation parts remain at the same work station. The product is moved through each station as work progresses.**

**This facility, as most others visited (non-marine), is Primarily an "assembly" plant with little or no detail fabrication. This concept of stationization places a major emphasis on kitting of material for each work station and to the sequence of component installation.**

#### **3.2.5 General Electric (Locomotive )**

**The product of this facility is heavy duty railroad locomotives.**

- a. Average weight - 160 tons.**
- b. The production capacity is 2 units per day.**
- c. The production work force is 1800 to 2200 employees.**

**This facility is completely stationized but varies from the other companies visited inasmuch as the entire manufacturing process is accomplished within one plant. The work begins with the raw steel fabrication and concludes with the deliverable finished product.**

**The production lines are not conveyors, but are geographically located and are planned to be station efficient, as opposed to "forced efficient. " (See 3.4, Item 5a for definition).**

**There are four major production lines that feed the main assembly line:**

- a. Wheel trucks and frame**
- b. Diesel engine**
- c. Motor / Gen, tractive line**
- d. Control cab**

**The Assemblies are moved through the sequenced work stations by bridge crane, wheeled dollies, and airlift devices. (The diesel engine block is placed on an air lift device, where it remains through all work stations until lifted onto the engine mounts ).**

**Note: The control cabs are completely pre-outfitted, including electrical harness, wiring, gauges, etc. prior to being fitted and welded to the locomotive bed.**

### **3.3 MARINE INDUSTRIES**

**The following shipyards were visited by the study group staff members, during the data gathering phase of the study:**

**General Dynamics (Shipbuilding )  
Quincy, Mass.**

**National Steel and Shipbuilding Company  
San Diego, Calif.**

**Equitable Equipment Co.  
New Orleans, La.**

**3. 3.1 General Dynamics (Quincy)**

**The current product is LNG tankers.**

- a. Capacity 125, 000 cubic meters.**
- b. The current contract is for eight ships.**

**The facility is stationized in the broad sense, primarily by manufacturing dictates.**

**The initial work breakdown for production effort is accomplished by a few highly skilled master planners. The detail working plans and day-to-day scheduling is accomplished by craft planners, reporting to the pertinent departmental superintendent. This system follows the "lead craft" concept, and is controlled by a cooperative effort of all craft Superintendents.**

**A major capital investment has been made in this facility for modernization in order to increase production capability. The principal areas of investment are:**

- a. A completely mechanized structural stiffener fabricator.**
- b. A mechanized panel line. Both the stiffener fabricator system and the panel lines are stationized with conveyers, (in the forced efficient concept).**
- c. Two additional graving docks bringing the total to five docks. Three are served by the addition of a goliath crane in the 1000 ton range.**

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**The work station concept is minimal in the overall operations of this facility.**

**3.3.2 National Steel and Shipbuilding Company.**

**The current product is (four) tankers, of 90,000 DWT capacity and a fleet oiler 37,000 DWT capacity.**

**This facility is completely stationized by design (See table 1), and makes extensive use of work stations throughout the design, planning and manufacturing process.**

**This yard in addition to completely established work stations, utilizes a computerized scheduling, planning and reporting data information system designed to assist production, production control and management in the accomplishment of all tasks necessary in the shipbuilding process. This computerized information system is utilized to:**

- a. Identify all ship components to the piece/part level.**
- b. Stationize the production cycle for all manufacturing disciplines.**
- c. Establish all production schedules, and provides data collection for monitoring purposes.**

**The computerized information system "by design" is flexible, in order to cope with the unexpected, and has been in use for four years with notable success.**

### **3.3.3 Equitable Equipment Co.**

**The current product of Equitable Equipment Company *is* offshore supply vessels and LASH barges. This study will address the LASH barge production line.**

**The barge production line is completely stationized, in the "forced efficient" concept, (i. e., the stations do not move until the preceding station is completed). The assemblies are moved through the work stations by wheeled dolly, and are assembled progressively until completion is reached.**

**The raw material, fabricated parts and/or purchased parts are delivered to the line by work station call-out, and specific operations *are* identified to be accomplished at each work station.**

**The work station concept is a vital part of barge production in this facility.**

## **3.4 WORK STATIONS AS RELATED TO SERIES PRODUCTION**

### **3.4.1 Non-Marine Applications**

**After evaluating the data that was collected during visits to non-marine industries, certain similarities and common denominators concerning operational techniques were apparent and are listed:**

- a. All plants visited were completely stationized (by design).**
- b. All production techniques were dependent upon a completely designed product prior to starting production.**

- . Extensive pre-planning effort (by work station) was made prior to "start production. "
- d. A major capital investment in tools and equipment was made, in some cases with a known decrease in the margin of profit per unit, but with a predicted increase in overall-profit due to high volume production.
- e. With one exception, all facilities visited were assembly plant only and depended upon "branch plants, " and/or subcontractors for a supply of detail parts and minor subassemblies.

The most pronounced variation in operational systems used by the companies visited was the application of work stations and the method of moving the products through the established stations. Two entirely different methods were observed.

- a. The high volume production rate where all materials are moved through the work stations by a continuously moving conveyor. Each work station is "forced efficient. " Detailed preplanning and extraordinary preventive measures are necessary to preclude line stoppages. The production schedule, units produced per day, week, etc. , can be established and met with accuracy, but this method is inflexible once the process has begun. This method of stationization was found to have very little to offer shipbuilding in general, but when related to series production it could be used to produce certain smaller parts and/or fabrications that are used in high volume.
- b. The alternate method of work station application observed was the practice of identifying each production operation of the facility to a work station, to plan and schedule all work effort

in sequence by station and to move the product through the operational sequence by the most practical and cost effective means. **This method creates a station efficient system as opposed to the "forced" efficient system. This method of stationization is more flexible and in some respects is similar to the lead craft concept of traditional shipbuilding methods. This work station concept after evaluation as to method(s) of application in non-marine and marine industries is concluded to offer a distinct potential advantage to a shipyard contemplating series production.**

#### **3.4.2 Marine Applications**

**The shipyards visited and/ or contacted during the study are to some extent stationized. The method of applying work stations to shipyard operations was found to vary from a casual application (work station by manufacturing dictates) to the completely established work station by design concept.**

It is the latter concept that will be discussed in the following portion of the report. One of the shipyards visited has completely stationized the entire **shipyard and identified the work stations by number (Table 6-1. ). This work station concept was evaluated as to the possibility of potential advantages to series production. This concept of work station application was found to offer distinct advantages to a shipyard engaged in, or contemplating series production. The possible applications and potential advantages are listed as follows:**

- 1. The individual work stations can be evaluated to determine precisely the station capability. From these evaluations an over-all "yard" capability manual can be accurately developed.**

2. **During the ship design phase, each drawing as released can be preplanned and all operational functions assigned by work station (See figure 6-1 ).**
3. **Upon completion of ship design and planning by work station the data can be tabulated and the following determinations made: (See figure 6-2, Example of Work Station Concept)**

- a. **Assembly Stationized**

**The work location is established and identified for this work effort to be accomplished on all ships repetitively with an anticipated increase in efficiency.**

- b. **Manpower**

**The total work effort per work station can be determined and the craft skill and numbers of employees per skill per station established. When once established the same work crew should be assigned to this work station for the duration of the series program.**

- c. **Lot Release**

**Once the stationization plan has been established, fabricated material requirements can be analyzed and developed as required to implement lot release objectives.**

- d. **Tooling**

**Tool requirements, portable perishable and capital tool jigs and fixtures can be identified and delivered to work stations as required by the schedule.**

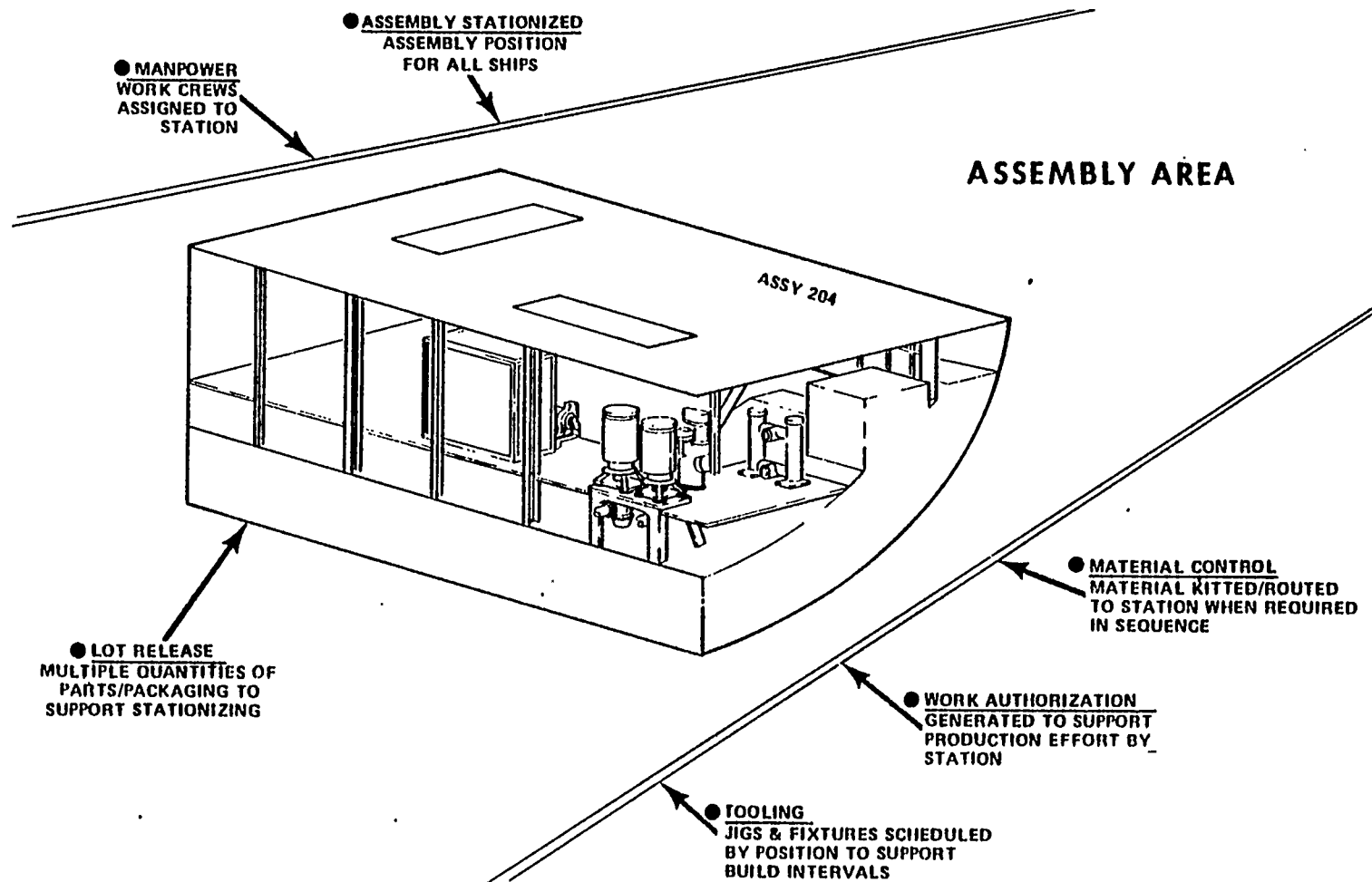
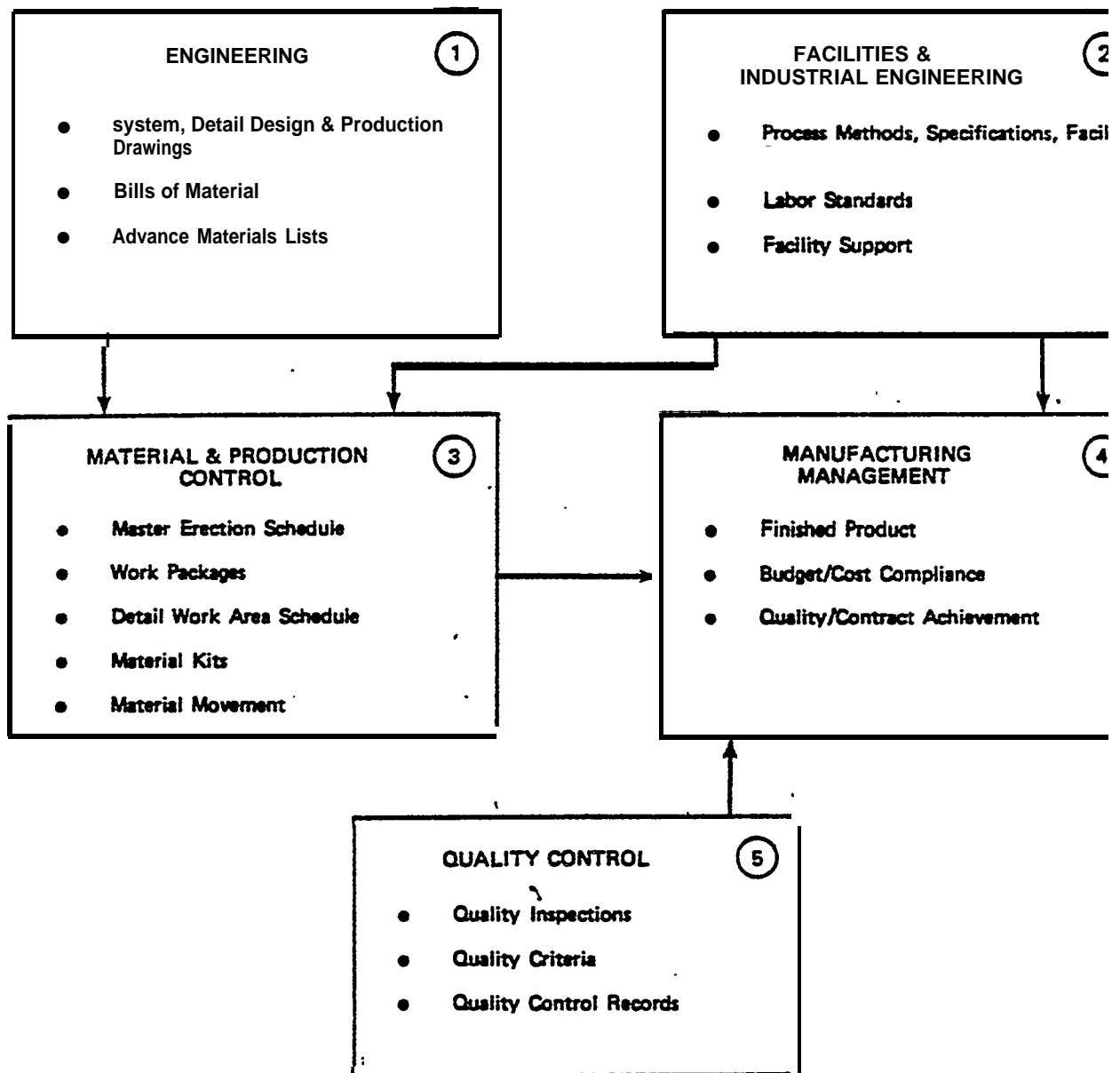


Figure 3-1. Example of Work Station Planning Concept

ORGANIZATION	APPLICATION OF TASK REQUIREMENT TO PP&C *
ENGINEERING	<p>1 Ship design to include production/design integration concept from the start. Production drawings and material lists explicitly contemplate the manufacturing process in detail. (These items prepared in conjunction with departments listed in 2 , 3 , 4 and 5 below.)</p>
FACILITIES & INDUSTRIAL ENGINEERING	<p>2 Methods and Industrial Engineering</p> <p>(a) Establish manufacturing standards fully consistent with ship design, (Engineering) and manufacturing processes throughout — man by man, for each operation hour by hour.</p> <p>(b) Define processes and tooling to implement each process and design all special tools, jigs, fixtures.</p> <p>Facility Engineering &amp; Maintenance</p> <p>(a) Ensure design/construction/availability of facilities is totally consistent with (a) &amp; (b). Design buildings. Perform facility engineering and maintenance functions.</p>
MATERIAL & PRODUCTION CONTROL	<p>3 Production Control</p> <p>(a) Create the Master Erection Schedules and the detailed work packages (TIP's) which initiate and control the production effort man by man, process by process; schedule material flow to match demand and expedite on a continuing basis. Implement methods and processes specified in 2a and 2b above.</p> <p>Material Control</p> <p>(b) Create the detailed material ordering sequences and the detailed schedules for delivery and warehousing. Maintain inventory and issue control.</p> <p>(c) Maintain physical control of material at all times from delivery in yard until delivered to shop or installation in the ship; take custody of material for all inter-shop movements and all movement between shops, storage and erection.</p> <p>Procurement</p> <p>(d) Make procurements as determined by material control.</p>
MANUFACTURING MANAGEMENT	<p>4 Supervise and direct the manufacturing work force, accomplishing tasks specified in Total Work Package (TIP's). The work of each group and individuals is defined by the operations sheets in the TIP's issued by Production Control. Accountable for meeting schedules, realization of standards from Material and Production Control, meeting cost objectives (added value of work centers).</p>
QUALITY ASSURANCE	<p>5 Quality Control</p> <p>Perform in-process inspections as stipulated on the operations sheets.</p>

NOTE: See Figure (D) for principal "outputs" of each organization.

Figure 4-6. Organizational Inputs to the Work Package



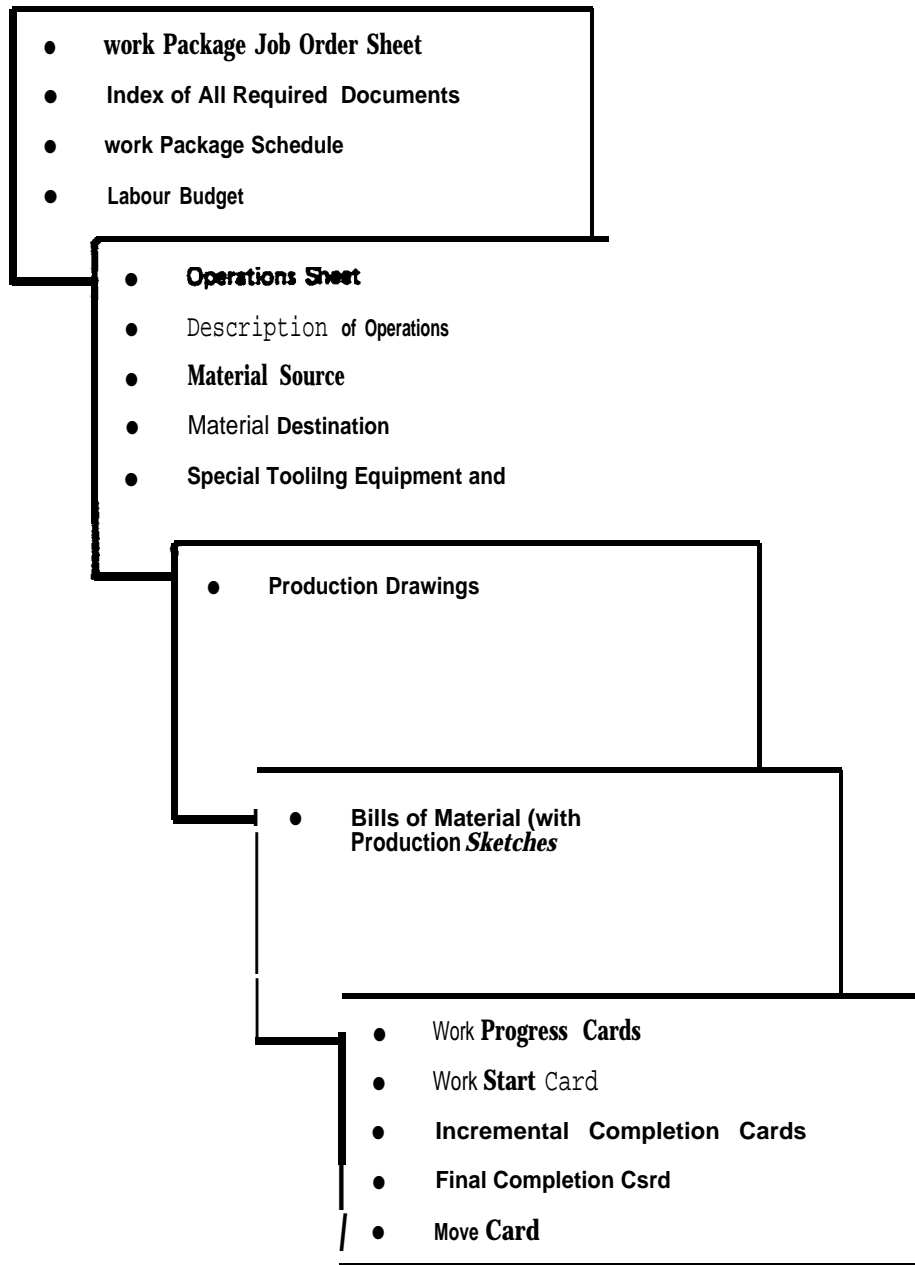
**Figure 4-7. Functional Inputs to the Work Package**

**4. 7.2 Work Package System Conditions.** It is highly desirable that a number of basic conditions exist for successful implementation of a detail Production Planning and Control System for series ship production. A brief discussion of these conditions follows:

- a . The first condition concerns production and design integration. It is most important that the manufacturing process begin with high quality, dependable and timely engineering data (working drawings, specifications, process descriptions, etc. ) fully consistent with the processes and manufacturing methods to be employed by the shipyard scheduled to build the series of ships.
- b. The second condition is that planning and scheduling control *must extend to the lowest practical task division level*. For example, a group of work stations along one of several principal assembly lines should be specifically identified to the individual *station level*. Work packages are identified to work stations and the tasks scheduled to be performed are determined by the capabilities of a specific work station.
- c. The third element is that the accounting system should be designed to collect the cost and performance data by each work package .

**4.7.3 Total Information Package and Total Material Package.** The work package includes a TIP and a TMP (figure 4-5) which complement each other. This compatibility is necessary to *ensure that the applied material will match manpower, standards, drawings, specifications, facilities, etc.* Therefore, the purpose of each work package is to furnish the production workers and supervision with sufficient information to enable them to complete the scheduled task with certainty and as scheduled.

- a. **Total Material Package (TMP).** The assurance of material availability is provided by the TMP. The total material package provides for systematic material kitting and staging, keyed to the work package requirement and scheduled to the work *station* assigned to accomplish the work. Material kits are assembled in accordance with the associated Bill of Material contained in the TIP. When practical, material kits are collected in a special staging area in advance of the scheduled production need dates.
- b. **Total Information Package Description.** The TIP contains all of the information necessary to perform the task defined in each work package. It consists of the major documents shown in figure 4-8. The purpose of each major document contained in the TIP is briefly summarized below:
  - 1. **Work Package Job Order Sheet.** Identifies the **tasks, schedules the work, allocates labor budgets and lists all required special documents.**
  - 2. **Operation Sheet.** Describes all operations required to perform the task, including the in-process inspections and material. The Operation Sheet also identifies all special tooling, equipment and fixtures required.
  - 3. **Production Drawings/Working Drawings.** These drawings define the specific product to be made, and the processes to be used in production.
  - 4. **Bills of Material.** Identifies and lists the materials required to perform the defined tasks.
  - 5. **Work Progress Cards.** Reports progress applicable to each work package.



**Figure 4-8. Contents of Total Information Package**

**4.7.4 Work Package Implementation Example.** The principal activities involved in implementing a typical work package are diagrammed in figure 4-9.

**The Master Erection Schedules (1) for the *first ship* is the *starting* point for all scheduled activities. The Master Schedule is the document which schedules the total building sequence.**

**A subassembly (noted WPO16- 100 on the Master Erection Schedule) is used to show the principal flow of TIP and TMP data and material under this production planning system. This particular subassembly is planned to be constructed at a work station in the subassembly area of the shipyard. Two lines of input feed the work station with information and material.**

**In the example, the descriptive and implementing instructions (items 2, 3 and 4) and the material required to accomplish the work are designated as items 6 and 7. It will be noted that labor is now shown as an input flowing into the work station. The inline continuous flow concept for *series* production calls for labor to be stationed there and for materials to flow through men and machines**

**Structural subassemblies (6) and outfitting kits (7) will be delivered to the work station as part of the TMP. It is important to note under this Production Planning and Control Concept that all deliveries are made by the Material Control Organization and all orders to move material are issued by that group. In this example, Production Control and Material Control are the organizations directly responsible for delivery of material and are functions under the PP & C Department.**

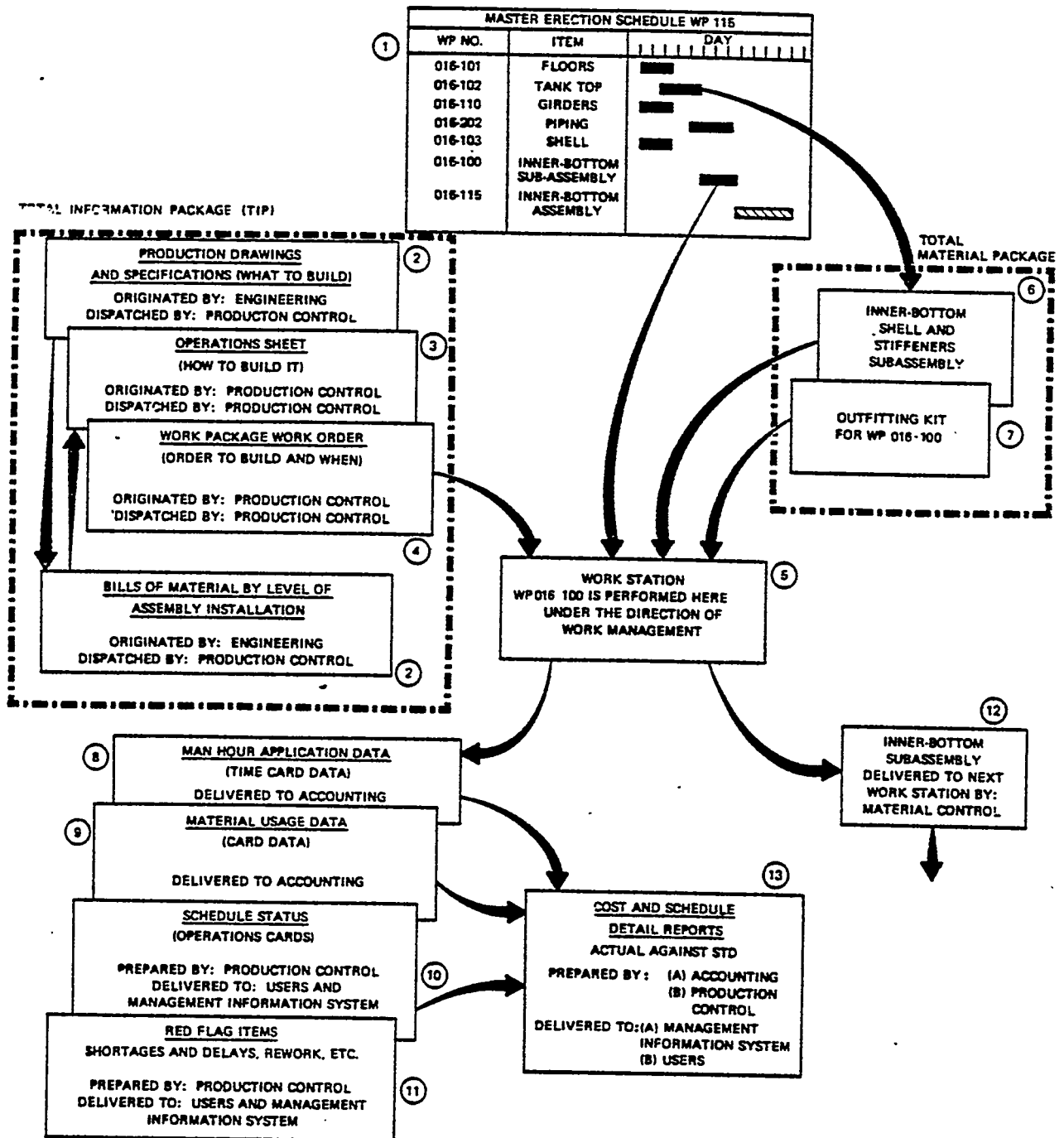


Figure 4-9. Implementation of a Typical Work Package

**Manhour application data (8) is recorded on the time cards and is incorporated into the Production Control Reporting System to provide for the costs and manhour expenditures which can be tracked by work package and to plans and schedules. This information is collected on a daily basis in EDP form.**

**Material Usage Data (9) is also collected by Production Control in EDP form and is used to compile material cost and prepare reports (13).**

**Schedule Status (10 ) is maintained on a continuing basis by Production Control and is used in a variety of ways including network charts, and at several management levels to track actual performance against scheduled performance.**

**Red Flag Items (11 ) include special reports dealing with material shortages; work delays; requirements for rework and any other special reports designed to fit a particular shipyard's problems or difficulties which may adversely affect schedules or costs.**

#### **4. 7.5 Reporting and Control Concept of the Work Package System.**

**Detailed progress reporting is an important factor necessary for the successful application of the Work Package System of production planning for series production. The framework for progress evaluation and control is based on:**

- a. PERT Networks. The production control organization prepares PERT or similar network charts which indicate the flow of work to be accomplished. These charts are used as graphic baseline for sequential scheduling of work packages. Constant updating of these charts by using work packages as units of production, provide in chart form, the amount of work performed, work to be accomplished, and the location of problem areas, etc.**

- b. Production Status/Progress Reports.** The production status/progress reports are EDP system outputs which report *status* by each work package number. This data can be summarized as necessary for progress reporting to the various divisions of the shipyard. The formats and content of these reports are designed to meet the needs of the different levels of the shipyard work force and management engaged in production of the series of ships .

Thus, the basic unit for implementing the manufacturing plan and for control of work is the relatively small and well-defined work package. When the Work Package System of production planning and *control* is properly installed and executed, all required series ship production work is documented and *status*ed in detail and progress can be closely monitored through the EDP reporting system and network charts.

#### **4.8 Comparison OF PRODUCTION PLANNING SYSTEMS FOR SERIES PRODUCTION**

In an effort to compare the suitability of each of the three planning systems for series production of large crude carriers, a merit value analysis was accomplished where in each system was graded, on a judgment basis, for its ability to satisfy the series production functional objectives and considerations as outlined in paragraphs 4.2 and 4.3. This was accomplished for single ship production as well as series production, so as to consider factors which may vary between the two situations.

**In grading the systems, a rating scale of 1 to 4 was established as shown below:**

- 1 = below average
- 2 = average
- 3 = above average
- 4 = superior

**Application of the merit rating system resulted in the compilations shown in figure 4-10 and the results are summarized as follows:**

SYSTEM	SINGLE SHIP PRODUCTION	SERIES SHIP PRODUCTION
Lead Craft	36	24
Group	37	40
Work Package	34	50

- 4. 8.1 Individual evaluations of each of these evaluation results merit elements (or similar type) are recommended due to the variations in shipyard facilities and methods of production which affect the choice of the planning systems and the development of planning methods for series production of ships.**

**Nevertheless, the element evaluation applied in figure 4-10 is considered to be a fair *comparison* of the three planning systems as would apply to most situations. The results reflect the equal merits of the Lead Craft and Group Systems for single ship construction, as well as the high desirability of applying the Work Package System to series ship production.**

PRODUCTION PLANNING SYSTEM MERIT ELEMENT	PRODUCTION PLANNING SYSTEMS																			
	LEAD CRAFT				GROUP / BILLS								WORK PACKAGE							
	SINGLE SHIP		SERIES SHIP		SINGLE SHIP		SERIES SHIP		SINGLE SHIP		SERIES SHIP		SINGLE SHIP		SERIES SHIP		SINGLE SHIP		SERIES SHIP	
	VALUE	RATE	VALUE	RATE	VALUE	RATE	VALUE	RATE	VALUE	RATE	VALUE	RATE	VALUE	RATE	VALUE	RATE	VALUE	RATE	VALUE	RATE
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1. Quantity of manpower required to manage and operate the PPLC organization by system.			X		X				X				X		X					X
2. Professional and skill level requirements for staffing PPLC organization.			X			X			X				X		X					X
3. System capability to provide information/interface for material procurement requirements, including expediting scheduling, make/buy decisions, etc.		X			X				X				X			X				X
4. Capability of system to provide information and visibility for kitting and movement of material to production areas and stations in a timely and efficient manner.	X				X					X		X			X					X
5. Capability of system to assist in planning for manpower requirements by skill.		X			X				X			X			X					X
6. Capability of system to assist in evaluating productivity of employees.		X			X				X			X			X					X
7. Capability of system to provide data required to evaluate production progress.		X			X				X			X			X					X
8. Flexibility of system to allow for incorporation of changes in ship design and equipment.			X			X			X			X			X				X	
9A. Cost of initial planning effort in relation to total dollar contract.			X			X			X			X			X					X
9B. Cost of maintenance program after initial completion of planning effort.		X			X				X			X			X					X
10. Capability of system to provide management with data for evaluating capacity utilization of existing facilities and equipment.	X				X				X			X			X					X
11. Capability of system to provide prompt and adequate data to assess impacts on production schedules due to work arounds.		X			X				X			X			X					X
12. PP system requirements for EDP equipment and personnel to implement the system and produce system reports, in terms of higher cost to program.			X			X			X			X			X				X	
13. System capability of identifying logical work units which can be scheduled, in accordance with detail manufacturing operations.		X			X				X			X			X					X
14. Capability of system to instruct production where and how work is to be performed.		X			X				X			X			X					X
15. Adaptability of system to various types of ship construction programs; i.e. military ships, single unit ship construction, small/large ships, etc.			X			X			X			X			X					X
TOTAL VALUE OF RATE SCALE CATEGORY	2	1	18	-	10	8	-	-	22	15	-	-	16	24	-	-	18	4	2	14
TOTAL VALUE EVALUATION RATINGS, BY SYSTEM, BY NO. OF SHIPS BUILT	30				34				37				40				34			50

Figure 4-10. Application of the Merit Rating System

**4. 8.2 Cost Comparisons.** In comparing the costs associated with initiating and maintaining each of the three systems, historical data was compiled which reflected the total manhour expenditure for the planning effort as expended in each of the three systems in support of various shipbuilding programs. By comparing the man-hours required to accomplish the planning effort with the total direct labor hour expenditure, a factor was developed which indicates the percentage of the total direct manhours which was expended for planning on a given program. This was accomplished on a random sampling basis as required to develop a representative amount of data. The findings were then plotted *in* order to demonstrate the variances in the manhour expenditures required for both the initial planning effort and a sustained supporting effort. (See figure 4-11. The conclusions to be drawn from this portion of the study are:

- a. Maintenance costs associated with the Group and Work Package production planning systems *are* reduced for follow-on ships.
- b. There is little reduction in total production planning cost when applying the lead craft system to follow-on ships in a series production program.
- c. The larger manhour expenditure required to accomplish the group or work package planning effort should produce a beneficial reduction in production manhours to be justifiable.

**4. 8.3 System Comparison Factors.** In summarizing the comparison of the three systems there *are* a number of factors which must be taken into account such as :

- a. While the Lead-Craft system requires the least amount of planning *manhours* to be expended in the planning organization,

**there is an additional planning burden placed on the production work force which is required to develop and complete the planning tasks.**

- b. With a major portion of the planning being accomplished by the production force there is likely to be a limited amount of time available to develop and implement manufacturing aids, method improvements, jigs, fixtures and special tooling, etc.**
- c. Using the lead craft approach there are limited benefits from learning being transferred to follow-on ships, since the system is dependent on the individual efforts of craft personnel and their involvement in follow-on work of a similar nature.**
- d. In view of the problems associated with the revision or alternation of a yard-wide effective system, the Group System for production planning is considered to be the most attractive program, particularly for those shipyards which are subject to a continuing change of conditions, such as, transition from single ship to multi-ship contracts or from military to commercial programs.**
- e. While the Group System can be altered to suit varying production techniques, it is not nearly as suitable for supporting work stationaization and detail machine-loading, on a large scale, as the Work Package System.**
- L In comparison to the Lead Craft and Group Systems, the Work Package System represents the highest cost, least flexible, most complicated and most extensive system reviewed.**

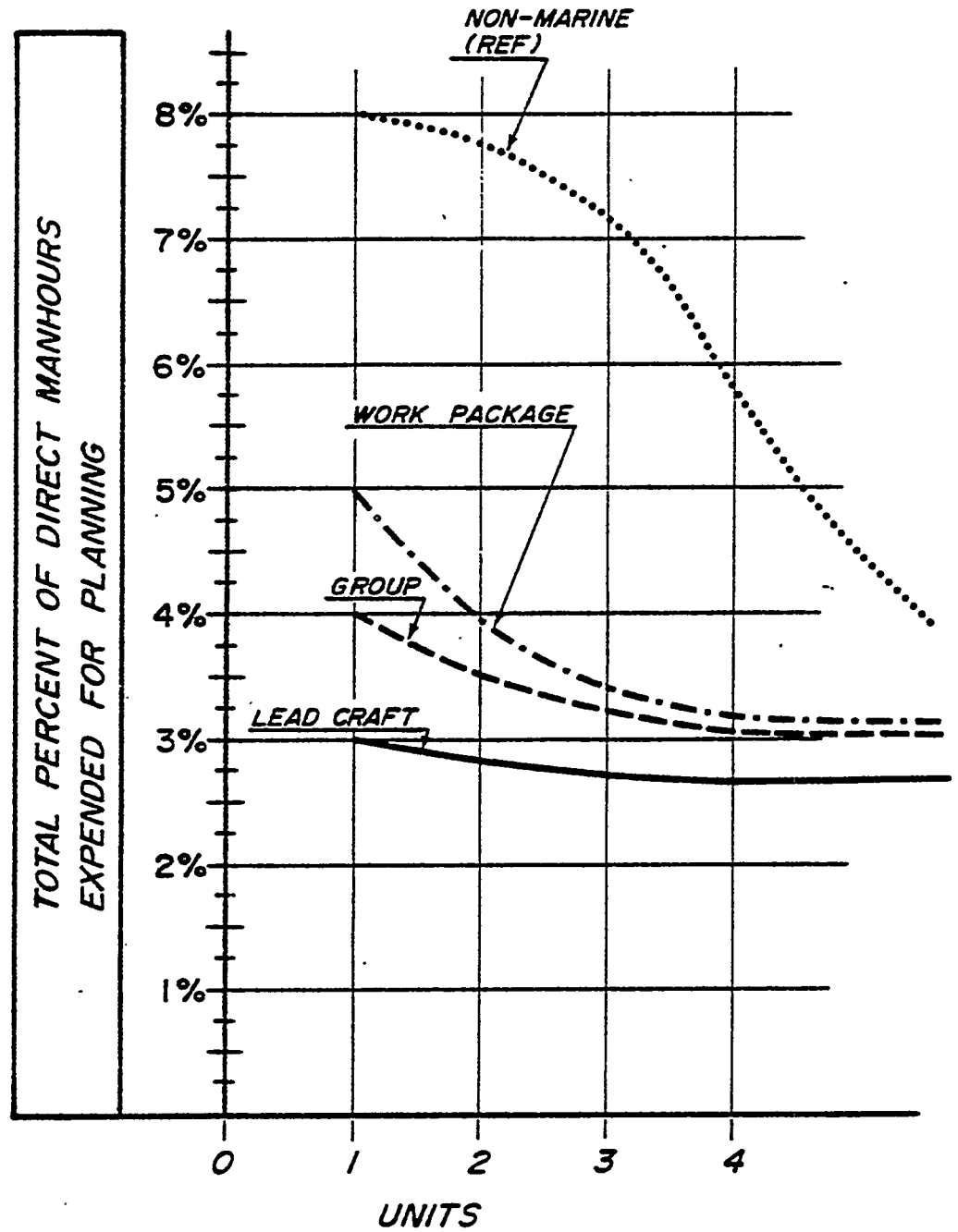


Figure 4-11. Production Planning Systems Manhour Cost Comparison

Nevertheless, when evaluated in terms of applying series production techniques, the Work Package System offers, by far, the greatest opportunity to guarantee actual benefits gained by maintaining a high degree of control over the total production process and ensuring the transfer of learning to the work force in repetitive operations. By the Work Package System breaking the work content down to more specific tasks, the planning effort is more suitable for implementation and control monitoring of work stationization and detail cost collection applications than the other two systems.

g As is true with the Group System, the planning effort in the Work Package System is transferable to follow-on ships and offers the opportunity to effectively identify and produce combined lots of manufactured items.

h. With these factors in mind, and recognizing that the choice of systems can only be made to suit specific shipyard conditions and resources, the conclusion from the comparison evaluation is that a positive effort should be made to adapt the advanced detail planning features of the Work Package System for series production of large crude carriers.

i The methods that shipyard may use to accomplish the above conclusion will depend largely on the production planning system which is in effect prior to the adaptation process. The end result of adaptation could quite well be some form of a hybrid system, custom designed to suit specific shipyard requirements. However, the end result should provide for the production planning system to accomplish the following:

(1) Analyze and break down the work content as represented by the engineering drawings and plan in detail the operations

**and work which are to be performed at work stations for producing specific parts.**

- (2) Analyze the total quantity required for individual common ship components and control the quantities produced to the advantage of the producer in lieu of the ultimate user (only that amount required by plans and specifications).**
- (3) Provide a cost accounting system which will provide for summation of costs necessary to produce single parts and for maintaining single work stations on a sustained basis with applicable output performance data.**
- (4) Identify as early as possible in the manufacturing cycle the requirements for special tooling, jigs and fixtures manufacturing aids and similar items which reduce production and material costs and encourage the application of these items to the manufacturing process.**
- (5) Maximize the benefits of specialized learning by assigning production tasks to specific work stations where personnel are assigned on a permanent basis to perform limited and repetitive tasks.**
- (6) Encourages the incorporation, on a sustained basis of method improvement applications and cost reduction innovations which are developed at all stages of the production program.**
- (7) Provide for development of a meaningful history of overall production costs and performance data which can be utilized to support future estimating and planning requirements.**

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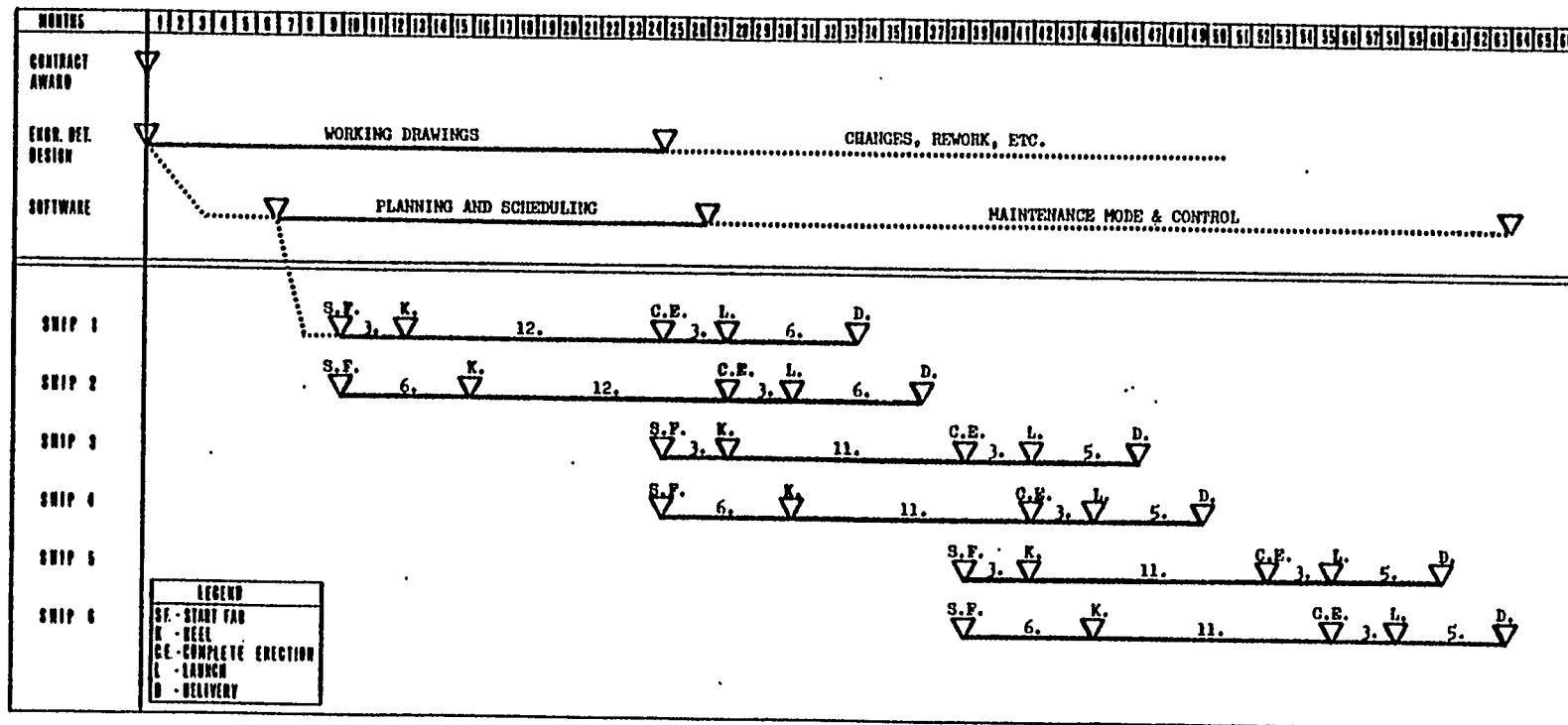
#### 4.9 PRODUCTION PLANNING SPAN TIME

Accomplishment of the individual planning tasks recommended for series production will most likely result in a requirement for the expansion of the planning organization and an extension of the time frame required to accomplish the more detailed planning effort. As a result, the development of the ship design must be changed from the conventional procedure, and *the* liaison between production planning and engineering must be accomplished as a strong coordinated effort, satisfying the requirements and efficiency of both disciplines.

Figure **4-12 presents a typical engineering-planning-Production cycle** which would normally be accomplished in shipbuilding. (Note the nine month interval between "Contract Award" and "Start Fab" for the first ship.) This figure is based on the assumption that in most U. S. Yards, utilizing only conventional production methods, not more than two (2) building berths would be available for the construction of ships of this size. It is also assumed that these yards would not have a lifting capability in excess of 200 tons. This reaction time is considered adequate for either the **Lead Craft or Group Systems**, but inadequate time for accomplishment of the detail planning required in support of the Work Package System. For series production, the recommended approach is somewhat different, as shown in Figure 4-13. This figure is based on the assumption that the steel fabrication capacity of most U. S. Yards, utilizing series production methods, would not exceed four **(4) ships of this size per year, and that support services and area would be adequate to support the movement of large modules or assemblies.**

In lieu of compressing the planning cycle required to support the earlier start of fabrication, production effort is held off while more complete engineering and planning work is accomplished. The nine month interval between "Contract Award" and "Start Fab" is extended to 12 months, and the production span time for the construction of each ship is reduced, due to the greater application of series production techniques.

# 150,000 DWT TANKER



# 150,000 DWT TANKER

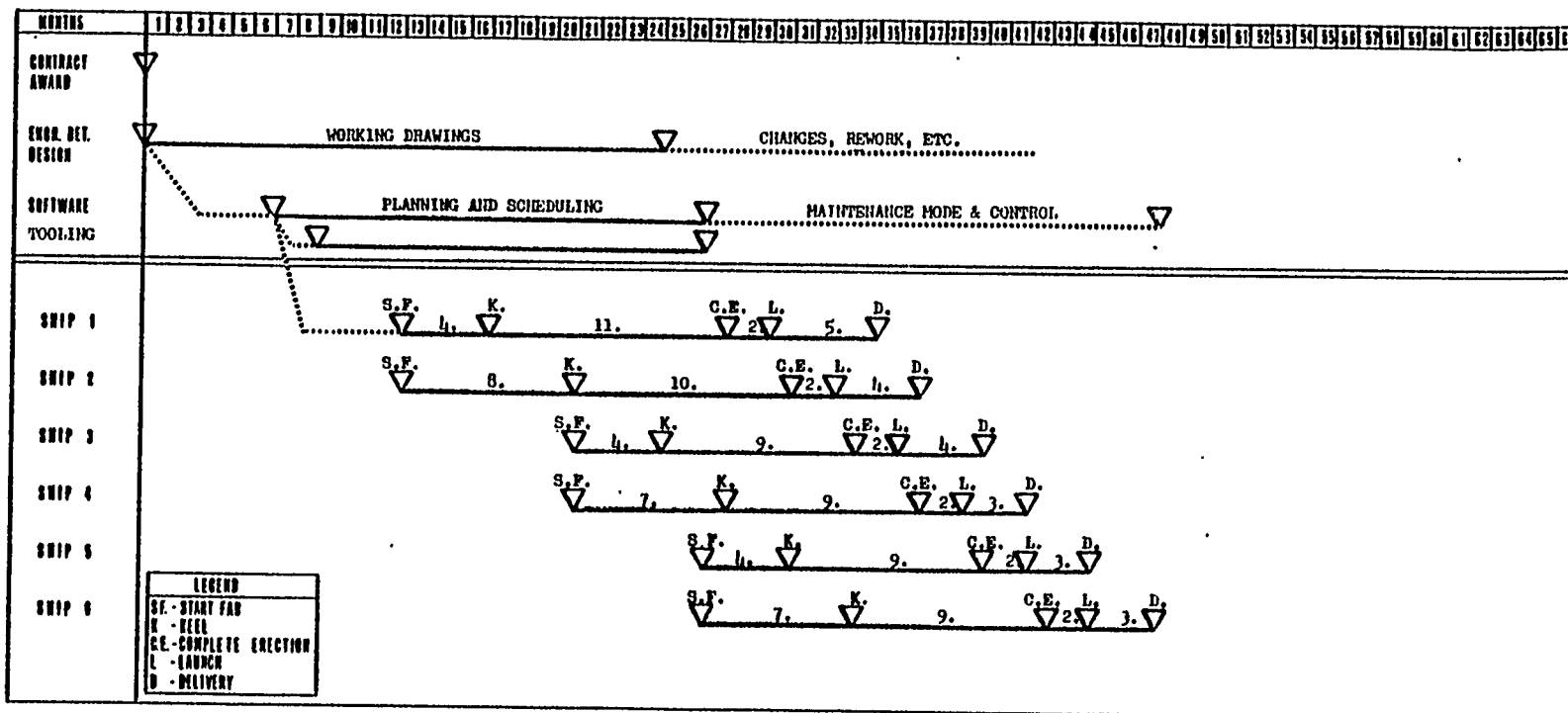


Figure 4-13. Lead Time Comparison - Series Production

The sequence shown indicates the same "Start Fab" dates for each of two ships so as to optimize the fabrication of "same" or "like" parts which could apply to conventional construction, but this can be arbitrary and will depend on the type ship and the production capability of the shipyard.

Factors affecting this aspect of the planning effort are included in Volume III, Part 1, entitled Facility Utilization which should be evaluated in conjunction with the planning section of the study.

#### 4.10 SUMMARY AND CONCLUSIONS

- a. Production planning systems utilized in shipbuilding may be described as centralized or decentralized, and are in the form of some variation of the following three basic systems:
  - (1) Lead Craft System
  - (2) Group System
  - (3) Work Package System
- b. The Lead Craft System represents the *minimal* formal production planning effort required prior to actual start of production, and is highly dependent on the involvement and experience factors of the production force. It does not favor major benefits due to learning and requires repetitious time and effort in support of follow-on ships.
- c. The Group System is more refined than the Lead Craft System, in that it allows for more detailed planning to be accomplished without in-depth involvement of production personnel. It is quite adaptable to relating the planning effort to a dependent sequence network and/or to a specific area of the ship, such as a breakdown by deck level or compartment.

- d. The Work Package System is the most detailed planning system investigated, and represents a strong effort to establish and locate most production planning outside of the production directorate. It is a system of high control, with an inherent capability for refined scheduling, statusing and cost monitoring on a sustained basis through a multi-ship contract. The elements of the Work Package can be organized to suit the user of the planning information as required to support specific machine loading or manpower requirements, etc.**
- e. While each of the production planning systems investigated have advantages and disadvantages for a given set of conditions, the Work Package System is the system most compatible with series production of large crude carriers and for potentially achieving reduced construction costs due to the benefits obtained by repetitive operations.**
- f. The production planning effort at most shipyards should be expanded for series production for large crude carriers regardless of the system which is presently utilized for conventional shipbuilding. Since both the engineering and planning efforts are essentially accomplished once for a *given* ship type, these efforts can be justifiably expanded for series production, since the greater manhour expenditure can be amortized against a multi-ship contract. The benefits gained by this additional one-time effort should accrue on each ship to be built, with a net reduction in the cost for each ship of the total series.**

**g . Major factors to be considered during series production plans are the implementation of "batch or lot" release programs, a the expansion and application of benefits at all levels due to learning within a single ship being carried across to a series of ships and ultimately brought forward to successive new ship building programs.**

VOLUME I I I

PART 4

PRODUCTION PIANN ING

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## VOLUME III

### PART 4

#### PRODUCTION PLANNING

##### 4.1 INTRODUCTION

In formulating the objectives of the production planning section of this study, it was necessary first to define the production planning as they are normally accomplished in support of the shipbuilding process.

For the purposes of the study, production planning is broadly defined as the total effort required to interpret the ship design engineering requirements and translate these requirements into a series of discrete tasks which must be accomplished in order to produce the desired ships; the tasks being oriented to the production facilities and organization available to perform the work.

In accomplishing this effort, shipyards have varied a great deal in their approach and many of the systems now in use are the product of an evolutionary process which has taken place through a period of years within each shipyard. Elements of specific production planning systems which have proven to be successful have been retained by shipyards, while elements of the system which have not met expectations have been eliminated or revised and elements of other systems adopted.

With this background in mind, it was established that the objective of this report was not to develop the ideal production planning system, but to identify the unique production planning requirements which are generated by a series ship production contract, and to assist the shipyards in accomplishing these requirements within the framework of systems currently in use.

## **4.2 DESCRIPTION OF THE PRODUCTION PLANNING FUNCTIONAL PROCESS**

**4.2.1** In spite of the wide range of production planning systems applied in shipbuilding, there is a fairly common understanding of what the system should provide and why the planning effort is such a key ingredient contributing to the success of the ship manufacturing process. In order to express production planning in terms of a common base, a functional objective outline of the four major production planning phases was developed which will allow for a comparison study of different systems. The outline for the four phases of the production planning function is as follows:

### **PHASE I**

Develop Production plan

- Management considerations
- **Facility and manpower utilization**
- **Schedule requirements**
- **Production capabilities**
- **Contract requirements**

### **PHASE II**

• **Implement Production Plan**

- **Analyze engineering drawings**
- **Issue planning paper**
- **Identify and prepare manufacturing aids**
- **Identify special tooling requirements**
- **Identify material requirements**
- **Establish budget or standard hours**

### **PHASE III .**

#### **Follow up on the Application of the Production Plan**

- **Monitor Performance of the Plan**
  - Productivity**
  - Schedule**
  - Material**
  - Manpower**
  
- **Evaluate Departures from the Plan**
  - Engineering changes**
  - Overruns**
  - Schedule slips**
  - Material shortages**
  
- **Apply *Corrective* Action to the Plan**
  - Revised planning**
  - Overtime**
  - Reschedule, recovery schedule**
  - Workarounds**
  - Subcontract**

### **PHASE IV**

- **Establish Historical Data**
  - Labor costs, manhours expended**
  - Performance to budget or standard hours**
  - Improved methods, applications**
  - Reusable tooling**
  - Performance to schedule**
  - Total accumulated costs**

**4.2.2 During phase I the broader aspects of the potential contract are analyzed, the impact on existing programs is evaluated, and a preliminary plan of action is developed in anticipation of the contract award. After actual receipt of the contract, this preliminary plan is expanded to include more specific and detailed information which is required to support the planning effort such as:**

- a. A master schedule is developed which pinpoints the timing of key events and includes, but is not limited to, the following scheduled items:**
  - (1) Start of fabrication**
  - (2) Keel laying**
  - (3) Landing of major equipments**
  - (4) Landing/erection of superstructure**
  - (5) Installation of shaft, propeller and rudder**
  - (6) Launch**
  - (7) Dock trials**
  - (8) Sea trials**
  - (9) Delivery**
- b. A manufacturing plan is developed which synthesizes the ships through the production facility, in order to ensure adequate capability and to identify new or unique requirements. (A detailed description of a recommended plan content is included in Volume 3, Part 1, entitled Facility Utilization.**
- c. Manpower requirements are analyzed and preliminary plans for adjustments are established in case there are projected conflicts within the existing craft mix or content of the total work force.**

- d. Unique or **unfamiliar contractual or design features** are analyzed, **and plans for successful accomplishment of these features are developed.** Major items which are subject to **make-or-buy justification** are also included in this phase.
- e. **A schedule for the accomplishment of the major support or software items is developed to support the anticipated production schedule and as established by the previously outlined master schedule.**

**With the information developed in this first phase, the detailed planning effort which is required during phase II can be accomplished with a full understanding of management goals and objectives for the on-coming program.**

4.2.3 In the second phase, the actual detail **planning effort is formulated:**

- a. **Engineering drawings are analyzed and the appropriate planning information is developed and released to the production department. Normally, this action is accomplished in a sequence which best supports the manufacturing process.**
- b. **Identification of requirements for jigs and fixtures, special tooling or other unique items is accomplished, and a course of action for the design, development and implementation of these items is completed.**
- c. **Material requirements are identified and normal material procurement processing is set in motion.**

- d. **Estimated manhours and budgets are developed to the level of detail which is required by the overall cost monitoring and collection system.**
- e. **The manufacturing plan is updated to include the necessary corrections and to incorporate detailed information resulting from other Phase II efforts.**
- f. **Detail production schedules are developed as required to support future monitoring of production progress.**
- g. **Manpower level plans are adjusted as necessary to ensure appropriate transition into the new production program.**

**At this point, the shipyard is prepared for the actual start of production work on the new program, recognizing that some new tasks may be completed in parallel with the previously existing workload.**

- 4.2.4 **In the third phase the actual production process has started and the major task at hand is the evaluation of actual performance against the plan and the timely corrections and adjustments of all departures from the plan. It is not to be construed that once a plan is established it cannot be revised. However, only those revisions to the plan which have been thoroughly investigated and adequately evaluated should be incorporated on a yard-wide basis. The methods for evaluating the shipyard's productivity position at any specific time during a construction contract vary a great deal from system to system and type contract. However, in an effort to reduce operating costs, shipyard are placing more emphasis on the requirements for accurate cost and progress reporting systems to accomplish this evaluation task.**

**This phase of production planning also generates valuable historical cost and production capability data which is analyzed and applied in Phase IV.**

**4.2.5 The fourth phase compiles actual cost and productivity data. The information gathered and developed in support of this last phase is utilized to identify and correct problem areas and to increase the accuracy of future estimating efforts. Systems and mechanisms for collecting this data are established in order to monitor progress against the plan; however, the use of this in-process data does not end with the termination of the construction program. The purpose of the fourth phase, then, is to compile the actual return cost data and arrange it in a meaningful order so as to verify its accuracy and encourage its use as reference material for both current and future programs.**

#### **4.3 SERIES PRODUCTION CONSIDERATIONS**

**4. 3.1 In a *series* ship production program there are a number of characteristics which directly effect the production planning process.**

With the opportunity to utilize the planning products on a repetitive basis, it becomes justifiable, **if not mandatory, to produce more reliable and cost effective production planning products. As a result of the requirement to successively build more than one ship of the same type, a number of tasks that are normally considered routine become the subject of particular emphasis, e. g.:**

- a. Batch or lot release**
- b. Physical kitting of material in advance of need**
- c. Work station implementation**
- d. Standardization of similar items**
- e. Make-or-buy material required**

- f. **Special tooling**
- g. **Jigs and fixtures**
- h. **Shop and machine loading**
- i. **Facility utilization**
- j. **Methods improvement**

**While these subjects are considered to be important in single ship production, they are rarely given adequate attention in these types of contracts' because of the lack of opportunity and the questionable amount of return realized in single ship contracts.**

**4. 3.2 In addition to the foregoing characteristics there are some specific characteristics within a specific production planning system itself which make it more or less suitable for series production than another system. The suitability and value of these individual characteristics or elements will vary from system to system and usually have different values relating to the number of ships to be built in a series. These specific characteristics include, but are not limited to the following:**

- a. **System reaction time required for incorporation of changes.**
- b. **System ability to coordinate and support work-around situations**
- c. **System ability to assist in minimizing production delays and disruptions due to material shortages.**
- d. **System ability to assist in distributing common source or lot material to a specific location to support a single ship of the series.**
- e. **Adaptability of system to sequential scheduling as required to support concurrent buildings.**

- f. System ability to assist in correlation of material requirements, as generated by the engineering drawings and processed through the procurement cycle for fabrication and installation in the finished product.**

**4. 3.3 With the factors enumerated in paragraphs 4. 3.1 and 4. 3.2 in mind, a review of production planning systems currently in use was conducted. An effort was made to evaluate each system's ability to support the Production Planning functions in a series ship production mode. Additionally, the factors identified in paragraphs 4. 3.1 and 4.3.2 were used as a basis for developing the Merit Elements applied in comparing the suitability of each of three planning systems to series production of ships (paragraph 4.8 and figure 4-10).**

#### **4 . 4 PRODUCTION PLANNING AND CONTROL SYSTEMS IN U.S. SHIPYARDS**

**4 . 4 . 1 Although there are a variety of approaches for accomplishing the tasks outlined in paragraph 4.2.1, there are certain factors which categorize the production planning system and establish the basic type of planning information which is generated by the process.**

**In general, production planning systems can be classified as being either centralized or decentralized. The centralized system is identified as one in which the production planning department assumes the responsibility for the control and execution of planning in addition to its responsibility for initial system development.**

**Under the decentralized organizational concept, the production planning organization acts as the lead for all planning, but delegates the detail development and surveillance responsibilities to the**

\*

operating departments and craft-orientated production areas. With this concept, the planning organization operates primarily as a coordinator of the overall production planning process, in lieu of being a controller.

4.402 **BASIC PP&C SYSTEMS.** The three basic *system* and their respective categories which were found to be representative of the planning functions in the U.S. shipbuilding industry at present are:

- a. Lead Craft System (Decentralized)
- b. Group System (Centralized)
- c. Work Package System (Centralized)

A detailed description of each of these systems follows; however, it should be noted that *features from one system can be adapted, in some cases, into another system.* This concept has been accomplished at Ingalls Shipbuilding facility, where the merger of two totally different production facilities required the development of a production planning system which would support both conventional and modular shipbuild

#### 4.5 DESCRIPTION OF THE LEAD CRAFT SYSTEM

- 4.5.1 *The Lead Craft System is decentralized planning system which delegates a major portion of the planning effort directly to the production organization. In utilizing this system, the production planning organization acts primarily to accomplish the material planning and functional coordination, while the production crafts perform the major portion of the detail planning effort as shown in figures 4-1 and 4-2.*

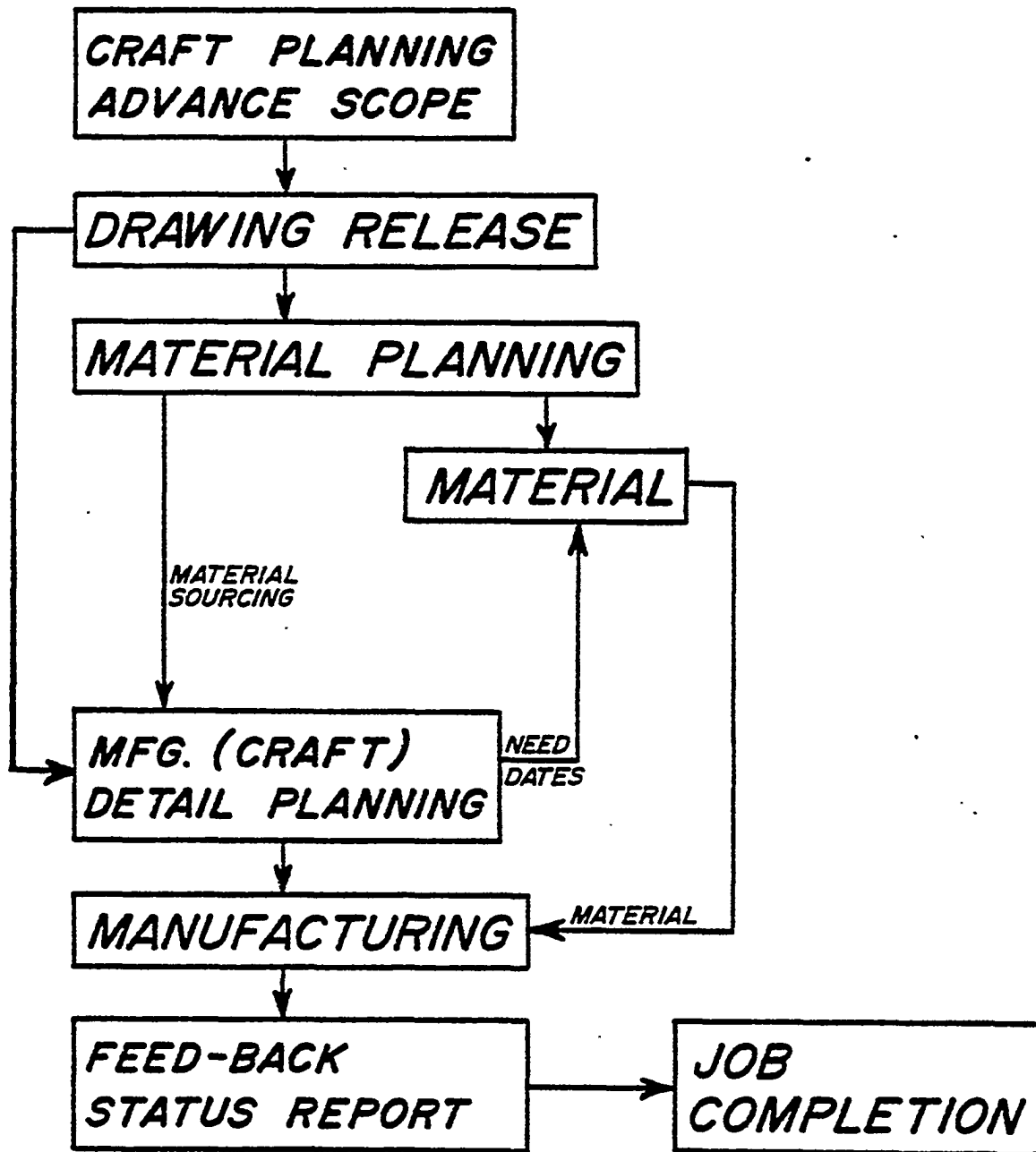


Figure 4-1. Lead Craft System Engineering/Planning Documentation Flow

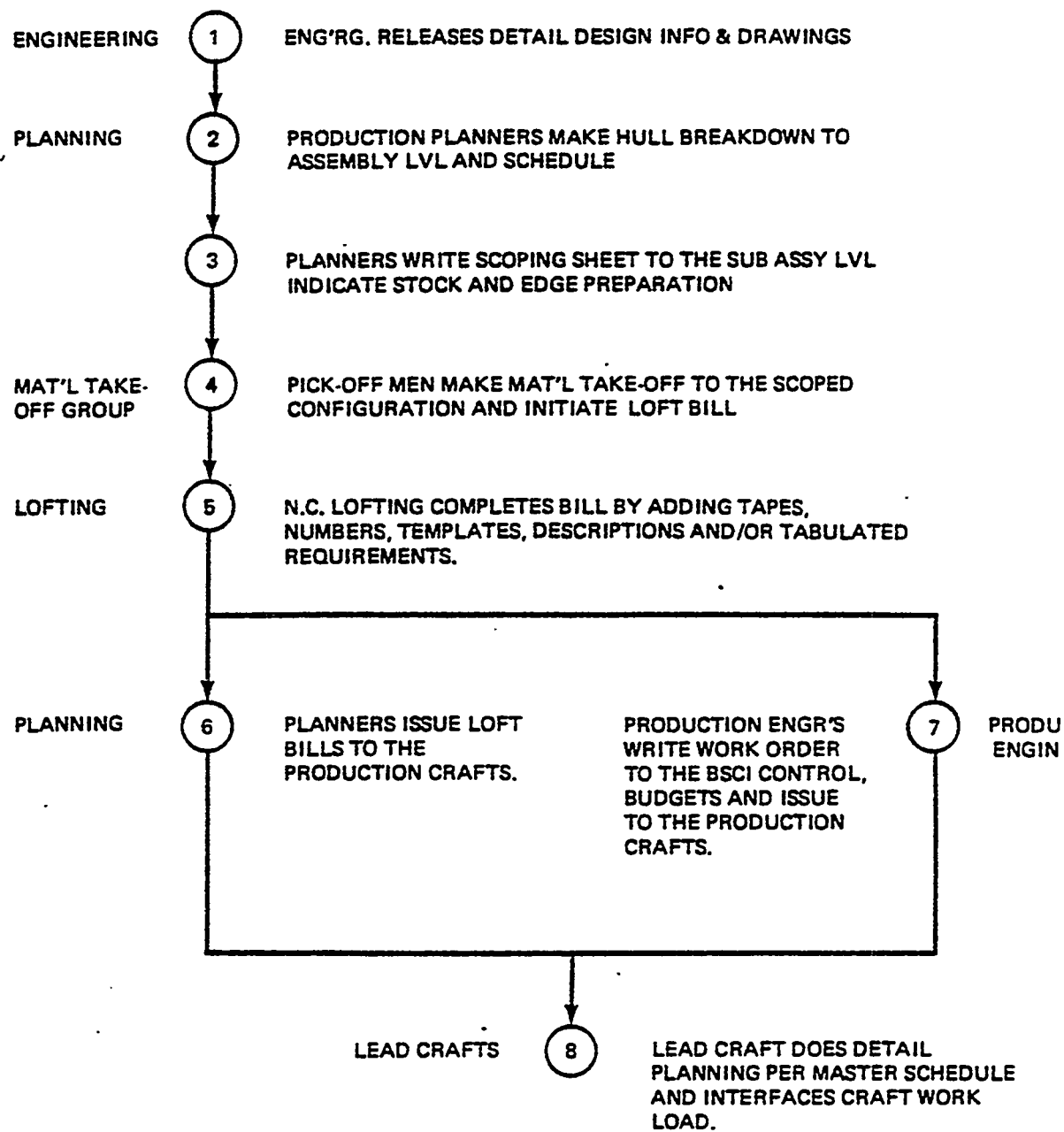


Figure 4-2. Lead Craft System Software Planning Cycle and Sequence of Events

**In *accomplishing* the actual productbn planning, a lead craft is established for a given task or area of responsibility, and all other crafts are cast in a supporting role. The lead craft responsibilities may vary during the different phases of construction, or in reference to alternate areas of the ship.**

**As an example, the hull department is assigned lead craft responsibility for planning and coordinating the key events associated with and leading up to the erection of the hull structure.**

**At that time, the lead craft responsibility could be shifted to some other craft to emphasize the dominant role played by that particular craft in completing a specific task or groups of tasks.**

**The machinery production department usually assumes the lead craft responsibility for the engine room and machinery spaces, with the hull department being transferred to a supportive type role for the se areas. The Hull Department responsibility is then in support of installation of foundations and other hull items which still remain to be completed. The Electrical Department may assume the lead craft responsibility at a point in time for the superstructure, and be required to coordinate and complete the installation of the communications and control equipments required in this area of the ship.**

**For each case the system remains the same, with the supporting crafts following the direction of the designated lead craft.**

**4. 5.2 Figures 4-1 and 4-2 represent the basic software flow cycle for the lead craft system. These figures show the planning functions which are accompli shed prior to accomplishment of the detail planning effort which follows.**

**In each instance, the required planning effort is oriented to supporting a key event schedule and coordinates the scheduling considerations affecting the planned task.**

- 4. 5.3 The accounting and cost-collecting *system* is usually limited to addressing the cost accumulated by each craft during the accomplishment of major task items. There is limited association of costs to the physical areas work is performed or association of specific costs to phases of construction.**

**Implementation of the Lead Craft System requires the cooperation and availability of a highly knowledgeable work force, thoroughly familiar with the various planning considerations which combine to make up the total production planning effort. The production force must also be capable of accomplishing their respective craft assignments without detailed instructions and without the benefits of other detailed pre -planning efforts.**

- 4. 5.4 Lead *Craft* Sequence of Events (Figure 4-2). In applying the Lead Craft System, the following general sequence of events are nor real accomplished in the order listed below:**

- a. planners divide the ship structure into discrete assemblies, as required to facilitate fabrication and erection of the hull structure.**
- b. Scoping sheets are prepared for each of the resultant assemblies which describe the parameters of the structural unit and outfitting considerations.**

- c. Detail planners or dispatch-writers prepare a dispatch document which identifies each piece to be manufactured and the sequence of operations required to accomplish the prescribed task.
- d. This information is routed for material sourcing, weight calculation and for determination of quantities to be manufactured.

Handling requirements for structural assemblies are analyzed and lifting plans are prepared for each unit.

- e. With the major portion of the hull planning effort completed, the remaining crafts define their respective tasks and plan the work to be performed to support the planned hull structure which has been previously determined.
- f. Pipe planning and fabrication is done in order to expedite the piping installations in both individual assemblies and the final erected ship. Pipe terminations and interface connections are included in the craft planning, so as to ensure compatibility with the structural configuration established by the hull planning effort.
- g. In planning the machinery areas, the machinists locate the major equipment, auxiliary machinery and associated foundations, and review land-on- ship requirements to prevent structural lock-out of machinery items.
- h. The remaining work disciplines are planned by the craft planners in a similar manner as described above; designating the areas where the particular work items are to be accomplished and establishing the sequence of events to be followed in completing a particular installation or task.

#### 4.6 DESCRIPTION OF THE GROUP SYSTEM

4. 6.1 The Group System of production planning and control identifies what, where, and when work is to be performed and the lead craft or shop responsible for accomplishment of the work. In general, no details as to how the work is to be accomplished by the production trades is provided to the shops by the production planning organization (other than to reference engineering drawings or prepare manufacturing sketches ). Figure 4-3 shows an example of the flow of documents applicable to the system. Figure 4-4 shows an example of a group system documentflow related to material and manufacturing work. .
4. 6.2 Definition of a Group. A group is defined as a division of related" work (usually a single labor account) which is intended to be perform at one time, under the supervision of one trade. Further subdivision may be by shop, ship or geographical area. Broadly termed, it is a grouping of work which is uniquely identified by a charge number and can be scheduled, budgeted and specifically assigned to an individual or department.
4. 6.3 Material Control and Collection. The Group Bill of Material defines parts and materials which a supervisor will normally require at one time to accomplish a group task. In some cases a Group Material Depot Concept is established, which physically kits material by group in advance of the required schedule and is held until needed. Material kits are issued to the production departments upon their request. The Group Depot Concept of handling material permits the production crafts to concentrate on production work, without the need for spending excessive time expediting material. Material availability reports are issued periodically to advise the production groups of material that has been collected.

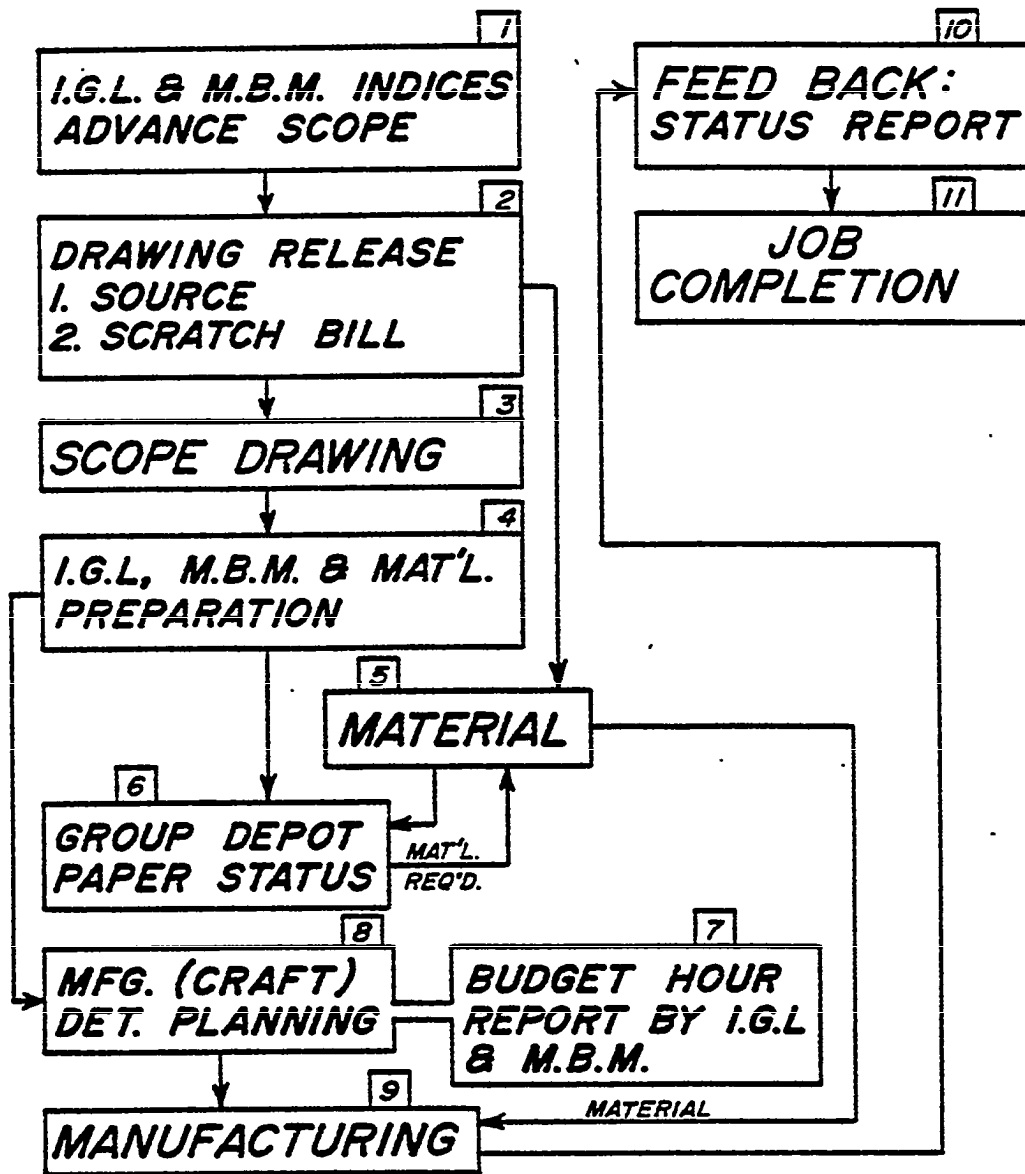


Figure 4-3 Group System Engineering/Planning Documentation Flow

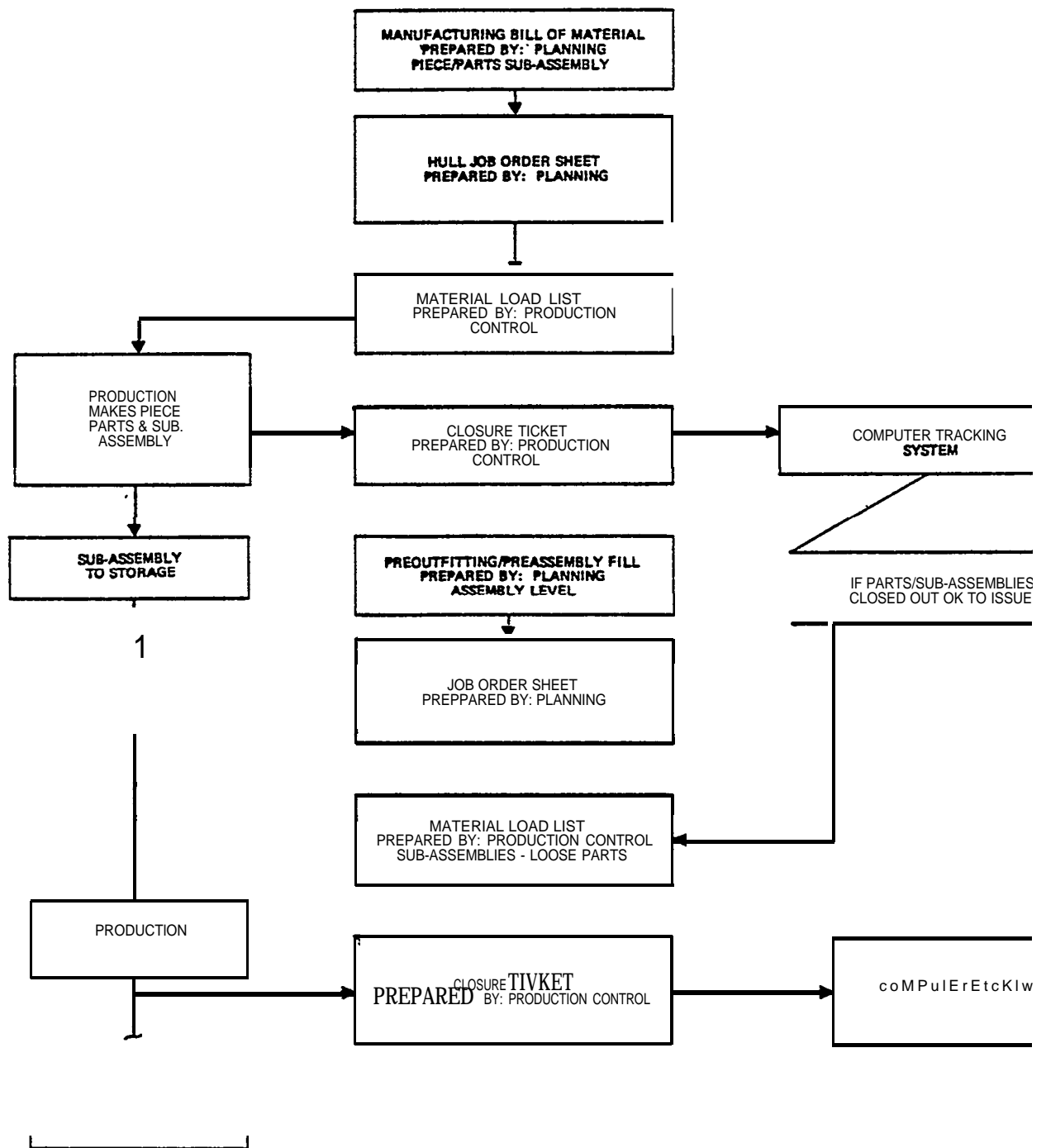


Figure 4.4. Group System Material and Manufacturing Work Documentation Flow

4. 6.4 Work Authorization Documents. The Work Authorization Documents, issued by production planning do not provide detailed descriptions of the work to be performed nor do they allocate detailed responsibilities for each work station. The work authorization document, by itself, authorizes work to be performed by a specific craft and authorizes charges to be made against a particular numbered and established account.
4. 6.5 Installation Group List Documents. The Installation Group List (IGL) is the document used to direct the performance of a unit of installation type work and usually contains the following information:
- a. Group title
  - b. Identification, source and routing of all material required
  - c. Start and completion dates
  - d. Group identification (accounting number ) for charging time
  - e. Budgets and standards for work to be performed
  - f. Other applicable data, as required (i. e. , lead department, ship installation area, plan number, special instructions nor notes, etc. )
4. 6.6 Manufacturing Bills of Material. The Manufacturing Bill of Material (MBM) is the document used to direct manufacture or assembly of a unit of shop work. The MBM contains the same basic information as the Installation Group Lists (IGL) described in paragraph 4.6.5.

- 4. 6.7 Pre-Outfitting/Pre-Assembly Bills (PPB). These bills provide planning data applicable to installation work in structural assemblies to be accomplished prior to their becoming an integral part of an assembly/module, or completed ship's hull.
- 4. 6.8 Construction Service Order (CSO) Bills. These bills authorize service type work such as rigging, scaffolding and manufacture of nondeliverable items; e. g. , tools and fixtures.
- 4. 6.9 Test Work Authorization Bills (TWA). These bills establish authorizations for the conducting required tests of equipment installed or to be installed.
- 4.6. 10 Progress Evaluation Using the Group System. It is essential that a worthwhile Production Planning System for series production of ships provide an accurate measure of progress for each ship under construction. Because the group is the defined unit of work in the Group System of production planning it can provide a workable basis on which to calculate shipbuilding progress. Progress status reports are based primarily on the following types of group data:
  - a. Installation Group Lists and Manufacturing Bills of Material - (Material scheduled for issue vs actual material issued)
  - b. Group Material Availability Report (schedule vs. actual)
  - c. IGL's /MBM's in process vs. scheduled to be in process
  - d. IGL's /MBM's complete vs. scheduled to be completed

By analysis of the above documents, progress of the ship construction program can be measured and problem areas identified.

4.6.11 Group Status Reports. A group index master (group schedule) is issued and updated on a periodic basis to provide visibility and status of work scheduled and completed.

#### 4.7 DESCRIPTION OF THE WORK PACKAGE SYSTEM

4. 7.1 The Work Package System of production planning and control is especially adaptable to in-line continuous flow production methods for producing a series of like products. This basic system is widely used in the U.S. in the automobile and aircraft industries and to a considerable extent in Japanese and Northern European shipyards. When this system is used in shipyards or other manufacturing industries, the fundamental criteria is detailed preplanning and monitoring of the production process to the lowest level practical against established plans. The procedures for the system include the development of a work package designed to match production units and production schedules which are compatible with the accounting and cost control system.

The work package serves as a means to define to craft superintendents, foremen and workers, what work is to be performed; where, when and how it is to be accomplished; the materials and tools required to do the job and the time schedule and manhours allocated to accomplish the work.

The Work Package Production Control Reporting Process is designed to report actual performance against scheduled performance for each unit of scheduled work. The typical work package consists of two basic parts: The Total Information Package (.TIP) and the Total Material Package (TMP). (See figure 4-5. ) Organizational and functional inputs to the Work Package System are shown in figures 4-6 and 4-7.

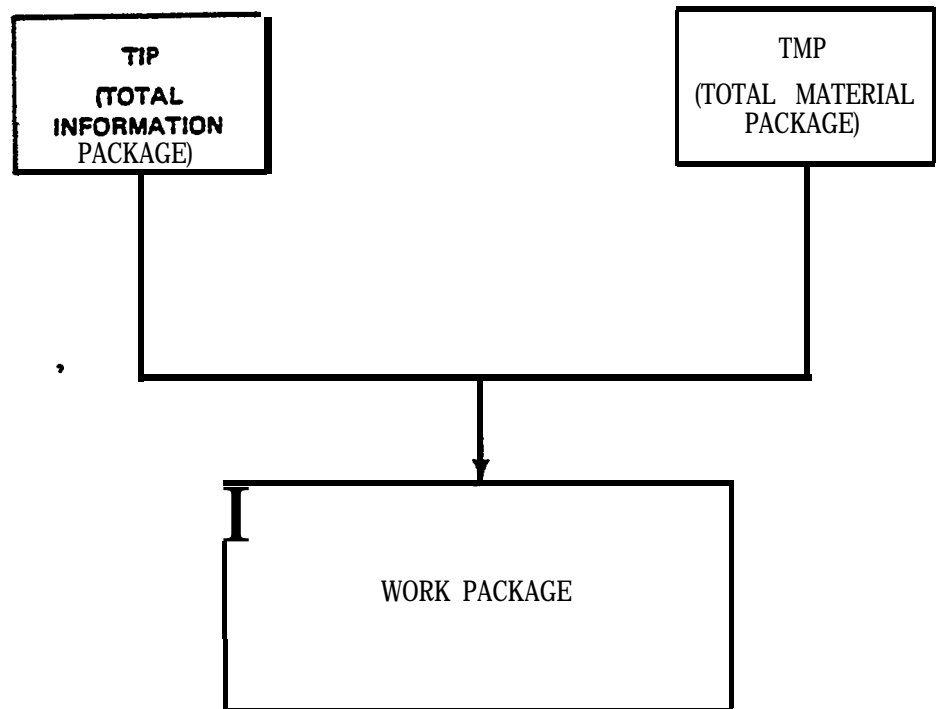


Figure 4-5. Basic Work Package Parts

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PART 5  
MATERIAL PLANNING

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VOLUME III  
PART 5  
MATERIAL PLANNING

5.1 INTRODUCTION

The objective of the Material Planning function is to provide the necessary materials when and where they are required, and at the least cost to the ship construction program.

In reviewing this task for series production, three aspects or distinct areas of this function were identified as being affected by the increase in number of ships to be built:

- a. Material Identification
- b. Batch Release
- c. Work Stations

In each of these study areas, accomplishment of the material planning function becomes more complex as additional requirements are generated by the series production contract. In the following text, the series production considerations are identified and the recommended approach for the accomplishment of the task is developed, within the limitations of the study objectives and without regard to existing shipyard systems.

5.2 MATERIAL IDENTIFICATION

The successful attainment of the material planning objective requires a material system closely correlated to the manufacturing system applied in building the ships. The major variance between the manufacturing methods for series production recommended in this

report and those widely used in conventional or single ship construction, center around:

- a. Assembly and pre -outfitting manufacturing techniques for construction of hull modules,
- b. Machinery packaging techniques for stern module outfitting,
- c. Assembly level working plans supplemented by piece/part plans,
- d. Maximum application of the work station/assembly line concept for manufacturing and assembling the many components which make up a series of complete ships.

The variances listed above should not cause major changes in the support system at a shipyard employing conventional ship construction methods. The variances which would cause change in such a case are the recommendation for developing assembly level working plans, supplemented by piece/part plans (Volume II, Part 7 of this report) and maximizing use of the work station concept covered in Volume III, Parts 1, 2, 3 and 4 of this report. These two recommendations would be cost effective and reduce the building time for a series of large crude carriers. However, if the series production recommendations are implemented by shipyards which follow strictly conventional methods for single ship construction, they may not only cause major changes in construction techniques but also necessitate some adjustments in the material support system. Implementation of assembly working plans, supplemented by piece/part plans should cause little impact on a conventional shipyard's material support system in the areas of purchasing, inventory control, subcontracting, material inspection, etc.

The major area of concern in this phase of the study is the development and application of a piece/part numbering system which will complement the objectives established for using work stations and assembly line production techniques for building a series of ships.

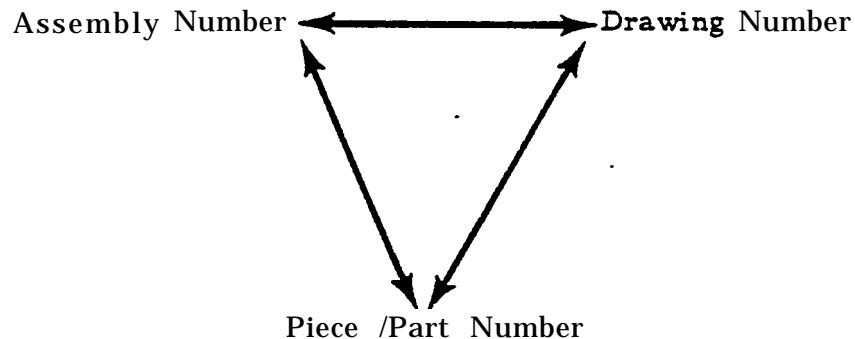
#### 5.2.1 Material Numbering Requirements

The material requirements identification task begins with the preparation of engineering drawings for both single and series ship production.

The identification task is more involved and critical to series production than single ship construction, since the application of series production methods cannot be effectively accomplished without a coordinated material identification system which provides the capability for a single piece/part to be identified in terms of:

- a. The engineering drawing which describes it;
- b. The installation unit which requires it.

In order to satisfy these series production requirements, a material identification system needs to be developed which provides for the correlation of the three basic material identification and application elements. These are:



### **5.3 SELECTION AND TIMING OF ASSIGNMENT OF PART NUMBERS**

**The assignment of numbers to parts, pieces, equipment, etc. , appearing on ship's plans should occur simultaneously with completion of the applicable drawings. These drawings should fully identify the item and the location of the item within a numbered assembly.**

**The selection of a numbering system which will provide correlation of piece/part numbers to drawing numbers and assembly numbers is largely a process of selecting a system which fits the needs of a particular shipyard. The system may utilize a wide variety of combinations of numbers and letters and may include manufacturing and assembly sequence information codes for contracts, hull numbers, etc. A fundamental consideration in selection of the number system is that the system be simple, as informative as possible and readily readable. Application and importance of piece /part numbers to series production manufacturing techniques is covered in paragraph 5.4 below.**

**Figure 5-1 represents an example of a piece/part numbering system which may be applied to the numbering of piece/parts during the development of ship's working plans.**

### **5.4 APPLICATION OF PART NUMBERS TO WORK STATION TYPE MANUFACTURING**

**Applying the work station/production line concept to a series of large ships involves moving large volumes of different configurations of material through designated work stations /areas on a pre-planned and scheduled basis. The numbers assigned to these parts and pieces become the communication language for tracking material and components through the various stages of the entire ship manufacturing process.**

<i>Customer Code Number</i>	<i>Series Contract Hull Number</i>	<i>Alpha Code Designates Mfg. Discipline or Lead Craft</i>	<i>Module Number (Combination Assemblies Prior to Final Erection)</i>	<i>Assembly No. (Combination of Subassemblies)</i>	<i>Subassembly No. (Made up of Pieces or Fabrications)</i>	<i>Fabrication (Combination of Pieces/Parts)</i>	
Cust	Hull	Alpha Code	Module	Assembly	Subassembly	Fab/Piece Item	
42	01	H	00	000	0000	0000	Example 1
42	01	H	01	000	0000	0000	Example 2
42	01	H	01	003	0000	0000	Example 3
42	01	H	01	003	0001 0001 0001 0001	0000 0001 0002 0003	Example 4
42	01	<b>H</b>	01	003	0000	0101 0102 0103	<b>Example 5</b>
42	01	H	01	003	0000	0004 0005 0006	Example 6

Figure 5-1. EDP Format - Manufacturing Work Breakdown Structure

---

cycle, from the design through material procurement and distribution to production and final delivery of the ship.

The application of assembly type manufacturing and systematic movement of parts, subassemblies, assemblies through the various stages of manufacturing requires the development of a program which divides the ship into carefully analyzed and defined sub-divisions. The typical sub-divisions are hull, module, assemblies, subassemblies and fabrications /parts and pieces as shown in figure 5-2 (this breakdown could apply to conventional as well as modular construction). The system should include an EDP program from which various types of manufacturing information can be extracted, including the level of installation of the various sub-units which make up the end product. The program should provide visibility as to what is to be manufactured where and the level of installation for each item. An example of this system, in EDP format, is shown in Figure 5-1.

This numbering system breaks the ship down using an indented part numbering system which relates the level of installation for each item and its sequential build up into the next higher assembly. In this manner each part may be tracked through the entire manufacturing cycle. The installation level of an item can be determined by the number designator as shown in the following examples:

Example No. 1 (Hull Level)

42 01 H 00 000 0000 0000

Translation = Customer No. 42

Hull No. 1

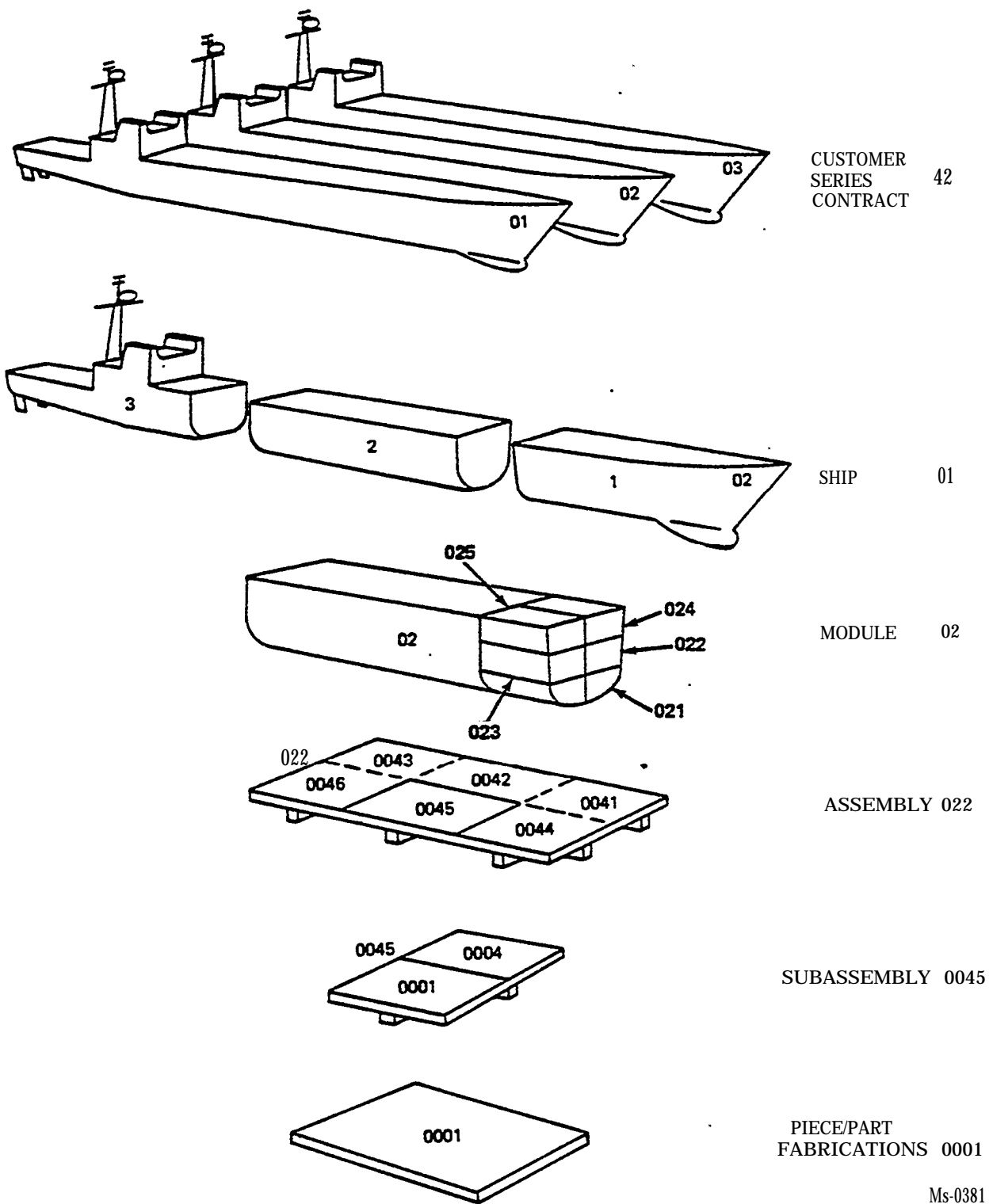
Example No. 2 (Module Level)

42 01 H 01 000 0000 0000

Translation = Customer No. 42

Hull No. 1

Module No. 1



Ms-0381

Figure 5-2. Typical Ship Subdivisions for Manufacturing Planning

Example No. 3 (Assembly Level)

42 01 H 01 003 000 0000 0000

Translation = Customer No. 42

Hull No. 1

Module No. 1

Assembly No. 3

Example No. 4 (Sub-Assembly Level Parts )

42 01 H 01 003 0001 0000

0001 0001

0001 0002

0001 0003

Translation = Customer No. 42

Hull No. 1

Module No. 1

Assembly No. 003

Sub-assembly 0001

Part Numbers 0001, 0002, 0003

Example No. 5 (Fabrication Level Parts )

42 01 H 01 003 0000 0101

0102

0103

Translation = Customer No. 2

Hull No. 1

Module No. 1

Assembly No. 003

Fabrication 0101, 0102, 0103 Direct to  
Assembly Level. (made up of parts 0101,  
0102, 0103)

Example No. 6 (Installation of Piece/Part at the Assembly Level)

42 01 H 01 003 0000 0004

0005

0006

Translation: Customer No. 42

Hull No. 1

Module No. 1

Assembly No. 003

(Part Numbers 0004, 0005, 0006 direct to the assembly level )

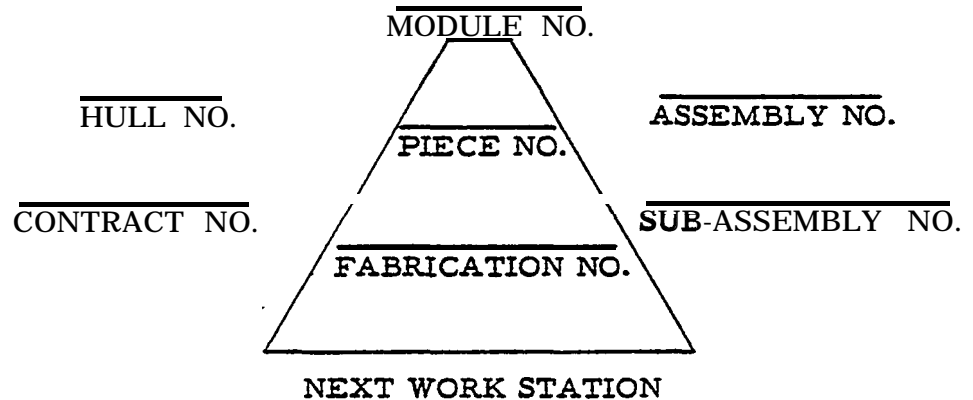
## 5.5 PHYSICAL NUMBERING OF PIECE/PARTS AND SUBASSEMBLIES

Pieces, parts and subassemblies must be physically marked in such a fashion that they may be identified and related to the proper drawing, bill of material, and operation sheets, and systematically located in storage areas near appropriate work stations. This is important for several reasons:

- a. Items requiring multiple process e-s should follow a definite sequence through the work stations. Good marking minimizes handling and assures sequencing for following operations.
- b. A record must be kept to show the status of operations, storage and final disposition of each piece. This record must be in such form that it will indicate when all of the items for a particular subassembly or assembly are complete and where each is located.

There are a number of marking systems which will satisfy this requirement. The following example of a marking applied during

the fabrication, subassembly and assembly stages will generally meet the requirements.



As can be seen, the above numbering system physically marks the item in such a manner that it describes its relative location in the ship and the subsequent work station to which it should be moved further processing. The above marking system provides an excellent method for identifying misplaced material and determining where it properly belongs.

#### 5.0 BATCH RELEASE MANUFACTURE OF PIECE /PARTS IN SERIES PRODUCTION CONTRACTS

A series production contract provides the builder an opportunity to apply mass production manufacturing techniques to produce the major parts and pieces required for the total run of ships. The design features of a tanker allows sizeable multiple applications of a variety of items used in construction of this type ship. Repetitive use items which have a high population count are in hull, pipe, ventilation and electrical disciplines and include pipe hangers, wire way hangers, brackets, clips, junction boxes, sheetmetal fittings, etc.

5. 6. 1. Identification of Candidate Items for Batch Release Manufacture in Series Production Contracts

Candidate items for batch manufacture are identified from the ship's working plans, specifications, parts lists or other available documentation which can be used to identify these types of items or to determine the quantities required for the total program.

Preparation of a candidate list of batch release items and quantities should be instituted as early as practical during the design development phase and finalized upon completion of the piece /parts plans phase by Engineering. Production Planning personnel assigned to the Engineering Department for the specific purpose of identifying batch manufacture items should assist in expediting preparation of these candidate lists. Production personnel are familiar with the yard's capabilities in terms of equipment and manpower skills required to produce the products and therefore should be able to make many on-the - spot decisions where an item falls within the batch manufacture category.

As previously stated, the candidate list should be started as early as practical, and in conjunction with preparation of ship's plans. One of the principal reasons for this is that many of the items which will appear on the list will not only be candidates for batch manufacture, but subject to make or buy decision making as well. Therefore, early identification of the items provides Procurement with lead time to solicit quotes from vendors and a make or buy and batch manufacture decision can frequently be resolved simultaneously.

Preparation of the listing of candidate items may be done in a format that best suits the needs of a particular shipyard and the specific building program. However, the listing should include at least the part number, quantity required by scheduled periods, ship application

Identification, work station involved in manufacture and unit and batch cost estimates (labor, material and overhead). The manufacturing plans and supporting erection schedules will provide the need dates for the majority of the multiple application items, subject to batch manufacture evaluation. The candidate lists should be periodically evaluated by appropriate material, manufacturing and production authorities for decisions applicable to the most economical quantity of each to be manufactured at one time and the requirement incorporated into the ship manufacturing schedules.

#### 5.6.2 Factors to be Considered in Batch Manufacturing of Material

The quantity of ships in the building program and the scheduled delivery dates of the ships are basic factors to be considered when selecting items and determining quantities of material for batch manufacture. Other factors to be considered in batch release manufacturing are:

- a. Cost and availability of different types of raw materials used in manufacturing multi-ship quantities of like items.
- b. Cost and expense incurred in caring for the items after manufacture (storage, handling, protection from the elements),
- c. Interest cost on the value of finished products held in storage inventory and unused for long periods.
- d. Yard manufacture costs vs. vendor supplied costs.
- e. Manpower and machine time availability to meet the scheduled need date for material. (Frequently during the ship construction cycle there are times that the workload

demand on certain crafts, shops, work stations is reduced to a low level compared to their potential capacity. During these low workload periods a special effort should be made to schedule "fill-in" batch manufacturing tasks. This type of production work planning and scheduling will minimize adverse effects on regularly scheduled work while simultaneously maximizing the benefits obtained by batch release manufacture by increasing the output of the same machines and work force ).

From the point of view of direct manufacturing labor cost, " the manufacture of quantities of like piece/part items at one scheduled time, is usually cost effective. "However, when applying the factors listed above and in consideration of manufacturing machine time availability, etc. , a decision to batch manufacture the total requirements of each like piece/part item during one production run is frequently invalid. The availability of manpower and high speed mechanized equipment capable of mass producing a large quantity of parts in a short period of time are only two of several factors to be considered in scheduling and determining quantities of items to be manufactured during one production run. The economics of batch manufacture and the extent of application depends to a great extent on the number of ships to be produced and the facilities available at a particular shipyard. Therefore, the precise benefits derived from batch manufacture have to be developed on a specific contract and Specific shipyard basis.

## 5.7 SUMMARY AND CONCLUSIONS

- a. As far as the operational requirements of a shipyard's material support system is concerned and within the scope and limitations of this study, there appears to be no major difference in performance required or techniques applied

when a major shipyard produces large crude carriers by series production methods or conventional methods except additional consideration should be given to following areas:

- (1) Material identification to the piece/part level and movement of material by this identification method through the work station concept of manufacturing and
- (2) Application of batch release manufacturing techniques to mass production of like items.

- b. A series production contract for large tankers provides the builder with the opportunity to apply mass production techniques to the manufacture of the pieces and parts required. The design features of a tanker allow sizeable multiple applications of a variety of items used in construction of this type ship. Repetitive use components which have a high population count are in the hull, pipe, ventilation and electrical disciplines. They include pipe hangers, wireway hangers, brackets, clips, junction boxes, sheet-metal fittings, etc. This area of series production has the potential of being an area where sizeable cost savings can be attained.
- c. The application and development of a piece/part numbering system which will complement the objectives established for using the work station concept and assembly production techniques for building a series of ships is paramount for attainment of those objectives. Volume II, Part 7, of this study provides additional detail on preparation of piece/part plans.

VOLUME III  
PART 6  
CRANES AND HEAVY EQUIPMENT

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## VOLUME III

### PART 6

#### CRANES AND HEAVY EQUIPMENT

##### 6.1 INTRODUCTION

This part of the report addresses three major subjects, each dealing with the lifting or moving of materials and structures in support of ship production. The three subjects are:

- a. Crane Capacity Study
- b. Economic Use of Equipment
- c. Heavy Load Moving Systems

The Crane Capacity Study is an analysis of the degree to which the total hull erection span time will be affected by variations in the maximum load which can be erected in a single lift.

The study is considered to be representative of the rationale and the trend toward increased crane capacity, and was a subject of particular emphasis and interest during the mid-term presentation of the report.

The subject, Economic Use of Equipment, is a further development of the Material Handling Equipment Study which was previously completed by Ingalls Shipbuilding as a part of the Ship Producibility Program. While not directly related to series production, this portion is included as being the type of information which can contribute to improved utilization of existing equipment and affects the forecast for future requirements generated by a series ship production contract.

The third subject, Heavy Load Moving Systems, is a preliminary review of the increasing variety, availability and adaptability of heavy-lift systems which have been developed in recent years and are successfully reducing the dependency on cranes for the movement of large structural assemblies. While the section could have been further developed to demonstrate and analyze applications to existing shipyards, additional pursuit of this subject was considered beyond the scope of this study and therefore was not accomplished. Hopefully, further development of this important subject will be included as a part of future ship producibility programs and studies.

In developing each of the above listed subjects, attempts to define specific areas of comparison between single-ship and series ship production met with little success. It may be that the original selection of the subject was, to some degree, not in keeping, with the series production objectives of the total study as the subjects evaluated are equally applicable to single ship production. (See description of Approach, Volume I, Part 2).

In spite of the above circumstance, the subjects were pursued as necessary to support related study areas (i. e., Development of the Mid- Body Configuration, Volume II, Part 1 ) and especially to respond to the requests which were made at the mid-term presentation.

## 6.2 CRANE CAPACITY STUDY

In an effort to develop a feel for the minimum crane capacity required to support production of a 150, 000 deadweight tanker and to evaluate the effects of variable crane capacities on the erection span time for a single ship, three midbody configurations were chosen from

Volume II, Part 1, "Midship Configuration, " of the study and used as "models" for the analysis.

- a. Configuration A-B (figure 6-1, page 6-4)
- b. Configuration C-A (figure 6-2, page 6-5 )
- c. Configuration D-A (figure 6-3, page 6-6)

For each configuration the midship section was "broken down" into discrete assemblies or units imposing a weight limitation of 200 tons on each unit. These assemblies were listed in accordance with the intended erection sequence. The number of lifts as well as the total weight of each lift was determined for each section.

It was assumed for the purposes of this study that there are no manpower or material limitations and that the space and equipment necessary to combine smaller units is available at some alternate location as required to make up the heavier assemblies erected in the 400 and 800 ton categories.

Table 6-1 (page 6- 11), 6-2 (page 6-12) and 6-3 (page 6-12) show the weights of each lift and the number of lifts required for each midbody configuration within the lift capacity limitations established for each category.

Note that in each case there is a limit to the use of the greater crane capacity and that erection and fitting considerations require the erection of smaller units (in spite of the crane capacity which is theoretically available). This would indicate that there is a significant benefit in crane utilization to be gained by using lower capacity cranes in combined lifts to suit specific requirements as opposed to the use of a single crane of maximum capacity.

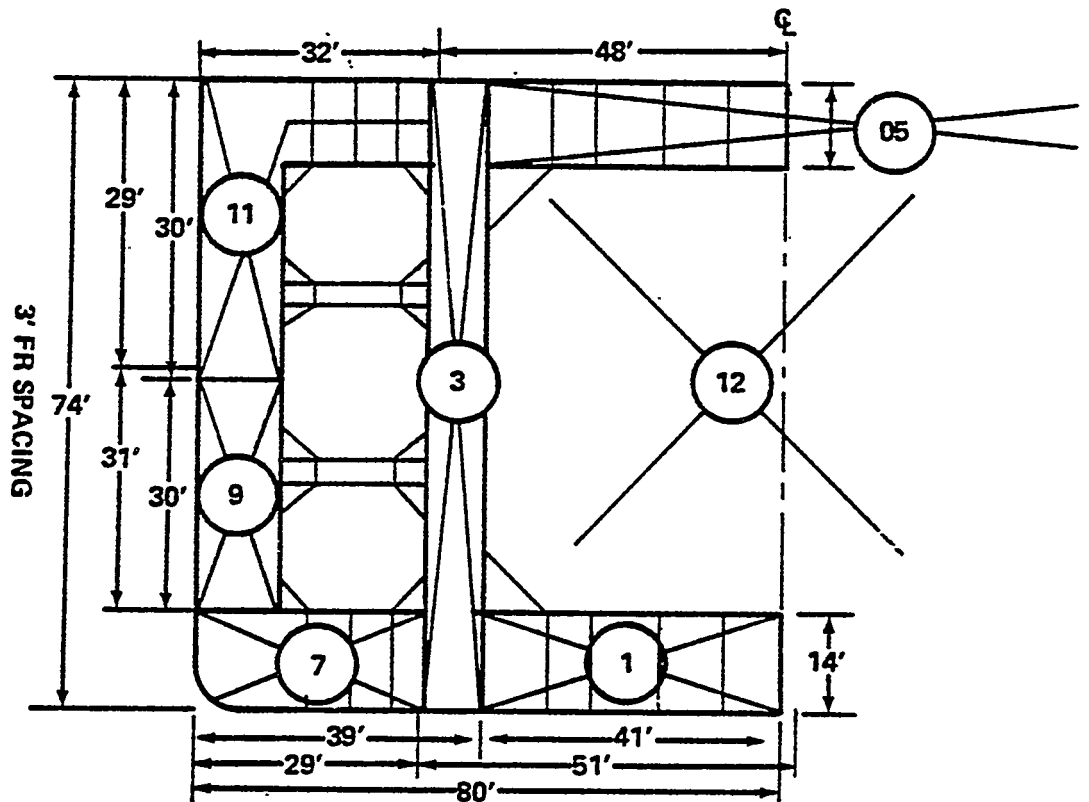
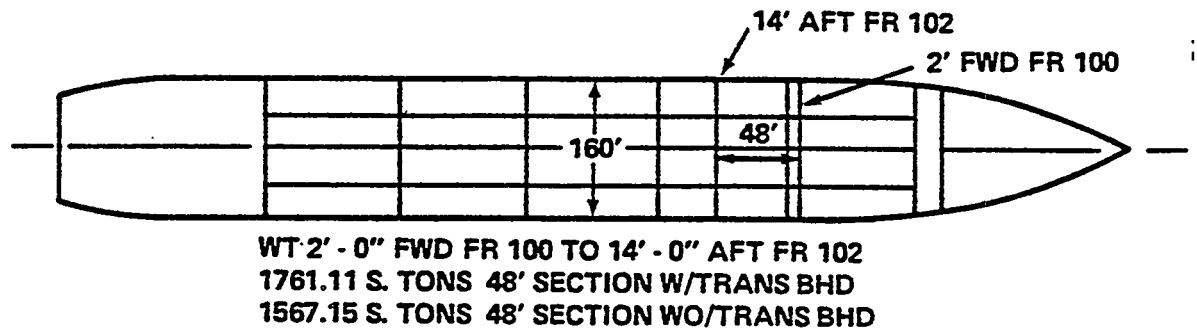


Figure 6-1. Configuration A-B

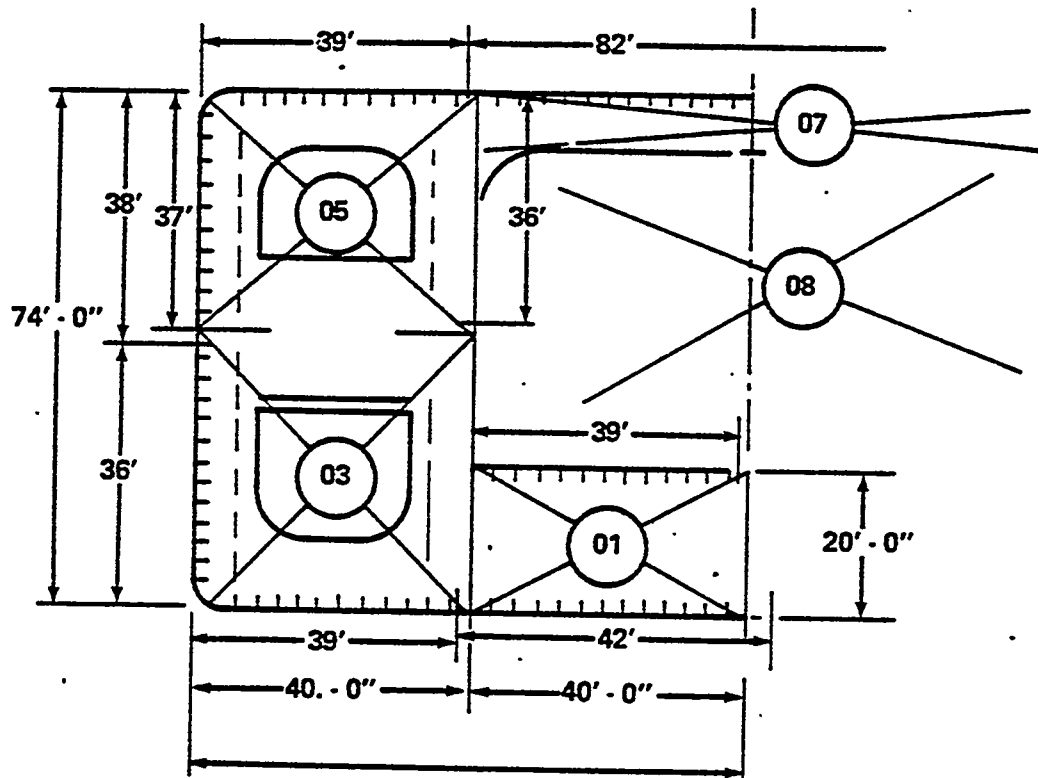
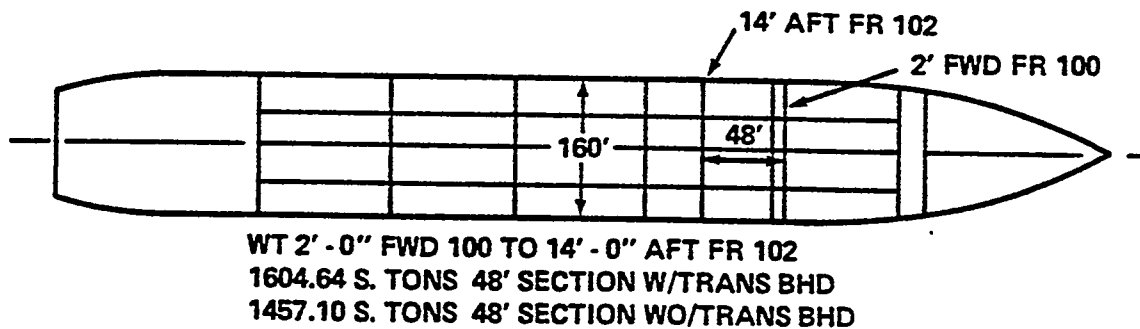


Figure 6-2. Configuration C-A

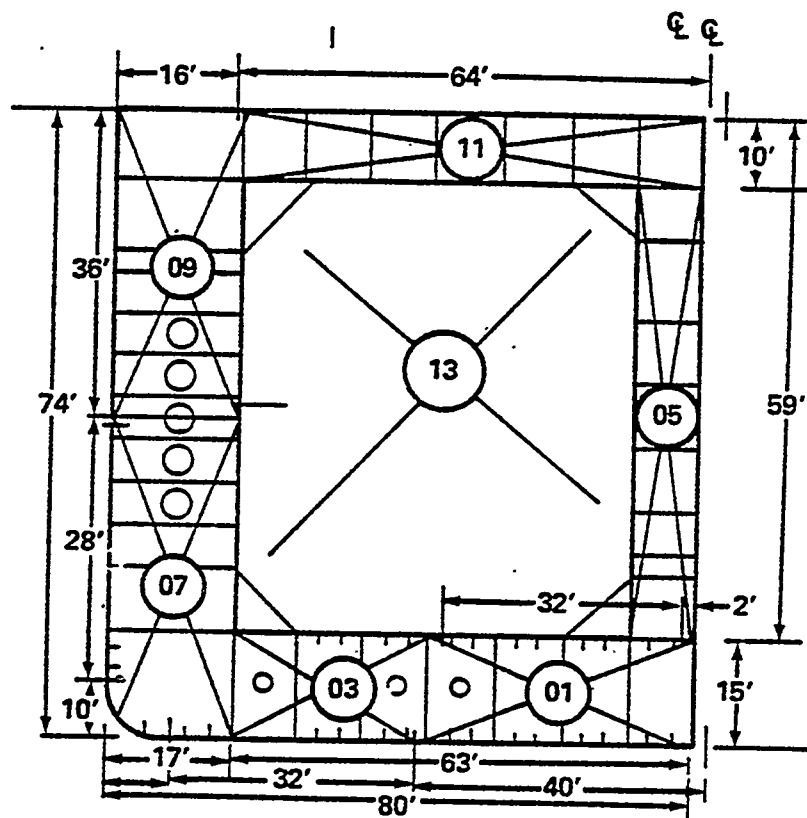
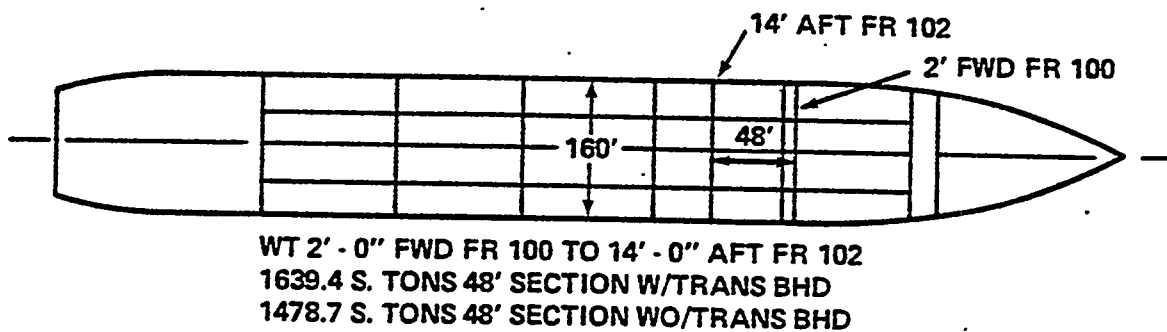


Figure 6-3. Configuration D-A

Recognizing that the time span to accomplish these lifts is much less than the time required for fit- up and welding of the unit after erection, configuration C-A was chosen for further investigation. An estimate of the fit and weld times for each assembly in this configuration was made to further evaluate the effects of crane capacity on the total erection span time.

These data were developed in accordance with how the units would be erected in each of the three lift capacity categories, and the total time required for fit and weld was established for each case as shown in table 6-4 (page 6-13), table 6-5 (page 6-14), and table 6-6 (page 6-15). A summary of this data is shown below.

#### Total Manhours Required for Fit and Weld at Erection

	200 Ton Lift Capacity	400 Ton Lift Capacity	800 Ton Lift Capacity
Total Fit	3,074	2,327	1,563
Total Weld	5,661	4,262	2,709
Total Manhours	8 , 7 3 5	6,599	4,272

These hours reflect the total fit and weld manhours which will be expended at the final erection position. The lower totals in the 400T and 800T categories do not represent a reduction in manhour requirements due to a greater efficiency, but are the result of more work being accomplished at some alternate location, or "on the ground, " prior to final erection.

The lower totals do represent an opportunity to reduce the total erection span time required for the erection of the mid- ship section at the final erection position. By applying a standard productivity rate to the respective total estimated hours to fit and weld each assembly, the total hour estimate was converted into "elapsed" hours or elapsed time required to fit and weld each unit as shown in table 6.7 (page 6- 16), table 6-8 (page 6- 17) and table 6-9 (page 6- 18). These total times are summarized below.

**Total Elapsed Hours Required for Fit and Weld at Erection**

	200 Ton Capacity	400 Ton Capacity	800 Ton Capacity
Frequency of lifts	183	144	72
Elapsed hours per frequency	742.6	542.7	275.2
Total Elapsed hours per Midbody	6,415.2	4,472.7	2,455.0

Based on the total elapsed span time for the fitting and welding of a complete midbody section, the data was further developed in an effort to evaluate the effect of variation in crane capacity in terms of ships per year.

Assuming a conventional erection procedure; that is, erection of two units simultaneously, as would be accomplished by erecting forward and aft of the mid-ship keel assembly, the total elapsed span time would be reduced by approximately 50 percent.

With a five-day work week for two shifts over a period of forty-eight weeks per year, there are 3, 840 available "work hours" to be utilized per erection location. Utilizing two locations, as previously described for the conventional erection sequence, the total available work hours are then multiplied by two, for a total of 7, 680.

The number of ships year can now be computed as follows:

$$\text{AVAILABLE MANHOURS} \div \text{HOURS REQUIRED PER MID-BODY SECTION} = \text{SHIPS PER YEAR}$$

Application of this formula is demonstrated as follows:

200 Ton Lift Capacity

$$7,680 \div 3,207.6 = 2.4 \text{ ships/year}$$

400 Ton Lift Capacity

$$7, 680 \div 2,236.4 = 3.4 \text{ ships/year}$$

800 Ton Lift Capacity

$$7, 680 \div 1, 227.4 = 6.3 \text{ ships/year}$$

It should be noted that the resultant ships per year figure represents the erection of the total parallel midbody of the ship, but does not include an allowance for the bow and stern sections.

By expanding these figures to suit a varying number of building positions, the following summary table was developed, which indicates the increased production rate which can be effected by erecting larger units of a given ship.

## SUMMARY - SHIPS PER YEAR

No. of Building Positions	200 Ton Lift Capacity	400 Ton Lift Capacity.	800 Ton Lift Capacity
1	2.4	3.4	6.3
2	4.8	6.9	12.5
3	7.2	10.3	18.8

### 6.2.1 Crane Capacity Conclusions and Recommendations

- a. The study results are representative of the rationale which has been used to justify the installation of "goliath" type cranes, as is the trend in many foreign shipyards. The larger crane capacity must be coupled with an equivalent capacity to fabricate larger structural units, prior to erection, in order to use the greater capacity advantageously. The tendency to increase lift capacity is particularly attractive where there is a requirement to increase the output of ships per year while working around a "fixed" facility constraint, such as a graving dock, which cannot be duplicated within the facility for economic or practical reasons.
- b. The study results are not considered to be particularly surprising, but are included as a demonstration of the type of analysis which may be utilized to evaluate lift capacity in anticipation of a series ship production program.
- c. As mentioned in Volume III, Part 1, the "Facility Utilization" section of the study, the optimum facility is one that is "balanced" in capability throughout the production process. An increase in crane capacity would not be useful in the absence of adequate resources that are required to utilize and support the increased lift capacity.

- d. Cranes should, therefore, be sized in accordance with the maximum projected capability of the over-all facility, and not as required to meet the maximum lift anticipated for a specific program.

Table 6-1. 200, 400 and 800 Ton Lift Capacities for Configuration A-B

200 Ton Lift			400 Ton Lift			800 Ton Lift		
Assy No.	seq.	Tonnage	Assy No.	Seq.	Tonnage	Assy No.	Seq.	Tonnage
01	1	175	01	1	351	01	1	790
02	2	175	02			02		
12	3	194	12	2	194	03	Lower	
03	4	108	03	3	273	04	Lower	
04	5	108	04	4	273	06		
05	6	215	05	5	215	07		
06	7	166	08	6	227	12	2	194
07	8	166	10			05	3	215
08	9	77	09	7	227	03	Upper 4	777
09	10	77	11			04	Upper	
10	11	151				08		
11	12	151				09		
						10		
						11		

Table 6-2. 200, 400 and 800 Ton Lift Capacities for Configuration C-A

200 Ton Lift			400 Ton Lift			800 Ton Lift		
Assy No.	Seq.	Tonnage	Assy No.	Seq.	Tonnage	Assy No. .	Seq. I	Tonnage
01	1	188	01	1	377	01	1	695
02	2	188	02			03		
08	3	148	08	2	148	03A		
03	4	103	03	3	239	05		
03A	5	137	03A			08P		
04	6	103	04	4	239	02	2	695
04A	7	137	04A			04		
05	8	193	05	5	193	04A		
06	9	193	06	6	193	06		
07	10	116	07	7	116	08S		
						07	3	116

Table 6-3. 200, 400 and 800 Ton Lift Capacities for Configuration D-A

200 Ton Lift			400 Ton Lift			800 Ton Lift		
Assy No.	Seq.			Seq.	Tonnage	Assy No.	Seq.	Tonnage
01	1	145	01	1	289	01	1	524
02	2	145	02			02		
03	3	117	04	2	294	03		
04	4	117	06			04		
05	5	92	05	3	92	05	2	92
12	6	220	03	4	294	12	3	120
13	7	120	07			13	4	120
06	8	177	12	5	120	06	5	783
07	9	177	13	6	120	07		
08	10	113	08	7	215	08		
09	11	113	10			09		
10	12	102	09	8	215	10		
11	13	102	11			11		

Table 6-4. Erection Manhours - 200 Ton Lifts

Assembly Erection Sequence	Fit Manhours	Weld Manhours	Total Manhours
01 to 02	114	208	322
01 to 01	169	241	410
02 to 02	169	241	410
08 to 01 and 02	71	143	214
03 to 01	127	214	341
03 to 03	163	293	456
03 to 08	75	208	283
03A to 03	317	595	912
04A to 04	3 1 7	595	912
04 to 02	127	214	341
04 to 08	75	208	283
05 to 03	197	331	528
05 to 05	163	241	404
06 to 04	197	331	528
06 to 06	163	241	404
07 to 05	5 4	143	197
07 to 06	54	143	197
07 to 07	99	133	232
07 to 08	112	227	339
05 to 08	75	208	283
06 to 08	75	208	283
Totals	3075	5 6 6 2	8737

Table 6-5. Erection Manhours - 400 Ton Lifts

Assembly Erection Sequence	Fit Manhours	Weld Manhours	Total Manhours
01/02 to 01/02	339	483	822
08 to 01/02	71	143	214
03 to 01	127	214	341
03 to 03	163	293	456
03 to 08	75	208	283
04 to 02	127	214	341
04 to 04	163	293	456
04 to 08	75	208	283
05 to 03	197	331	528
05 to 05	163	241	404
05 to 08	75	208	283
06 to 04	197	331	528
06 to 06	163	241	404
06 to 08	75	208	283
07 to 05	54	143	197
07 to 06	54	143	197
07 to 07	99	133	231
07 to 08	112	227	339
Totals	2328	4263	6591

Table 6-6. Erection Manhours - 800 Ton Lifts

Assembly Erection Sequence	Fit Manhours	Weld Manhours	Total Manhours
01/03/03A/05/08 to 02/04/04A/06/08	188	417	605
01/03/03A/05/08 to same	496	775	1271
02/04/04A/06/08 to same	496	775	1271
07 to 05	54	143	197
07 to 06	54	143	197
07 to 07	99	133	232
07 to 08	112	227	339
07P to 07S	64	97	162
Totals	1563	2710	4273

Table 6-7. Total Elapsed Span Time - 200 Ton Lifts

Assembly	Frequency of Lifts Per Midbody	Elapsed Hours Per Lift	Total Elapsed Hours Per Midbody
01 to 02	10	37	378
01 to 01	9	56	508
02 to 02	9	56	508
08 to 01 & 02	5	23	118
03 to 01	10	42	422
03 to 03	9	27	244
03 to 08	5	24	124
03A to 03	10	52	528
04A to 04	10	52	528
04 to 02	10	42	422
04 to 04	9	27	244
04 to 08	5	24	124
05 to 03	10	49	492
05 to 05	9	27	244
06 to 04	10	32	328
06 to 06	9	27	244
07 to 05	10	13	134
07 to 06	10	13	134
07 to 07	9	33	297
07 to 08	5	28	140
05 to 08	5	24	124
06 to 08	5	24	124
Totals	183	742	6,415

Table 6-8. Total Elapsed Span Time - 400 Ton Lifts

Assembly	Frequency Per Midbody	Elapsed Hours Per Frequency	Total Elapsed Hours Per Midbody
01/02 to 01/02	9	56.5	508.5
08 to 01/02	5	23.6	118.-0
03 to 01	10	42.2	422.0
03 to 03	9	27.2	244.8
03 to 08	5	24.9	124.5
04 to 02	10	42.2	422.0
04 to 04	9	27.2	244.8
04 to 08	5	24.9	124.5
05 to 03	10	49.2	492.0
05 to 05	9	27.2	244.3
05 to 08	5	24.9	124.5
06 to 04	10	32.3	328.0
06 to 06	9	27.2	244.8
06 to 08	5	24.9	124.5
07 to 05	10	13.4	134.0
07 to 06	10	13.4	134.0
07 to 07	9	33.0	297.0
07 to 08	5	28.0	140.0
Totals	144	543	4473

Table 6-9. Total Elapsed Span Time - 800 Ton Lifts

Assembly	Frequency of Lifts Per Midbody	Elapsed Hours Per Frequency .	Total Elapsed Hours Per Midbody
01/03/03A/05/08 to 02/04/04A/06/08	10	31.4	314.0
01/03/03P/05/08 to 01/03/03A/05/08	9	62.0	558.0
02/04/04P/06/08 to 02/04/04A/06/08	9	62.0	558.0
07 to 05	10	13.4	134.0
07 to 06	10	13.4	134.0
07 to 07	9	33.0	297.0
07 to 08	5	28.0	140.0
07P to 07S	10	32.0	320.0
Totals	72	275.	2455.

### 6.3 ECONOMIC USE OF MATERIAL HANDLING EQUIPMENT

In an effort to assist in the evaluation of material handling requirements and to improve the utilization of existing equipments for series production of ships, a comparison was made of the various options which exist in material handling equipment for lifting and moving both steel plate and fabricated assemblies.

Utilizing the basic formulas which were developed and included in the "Material Handling Equipment Catalog; " selected equipment was analyzed and compared for given sets of conditions.<sup>1</sup>

Applicable data for several types of selected equipment was plotted in graph form so as to highlight the results of operational comparison under various conditions and to establish the specific points of cost effective intercept for each type equipment and condition. Use of these charts will assist a shipyard in selecting equipment which will **best suit the actual shipyard conditions and result in the most cost effective method of moving materials.**

Establishing the most efficient method of material handling is particularly important in series ship production due to extended production effort and repetitive material operations which will be required. This condition offers a significant opportunity for shipyards to develop and implement more efficient methods for handling material and to improve upon the utilization of material handling equipment.

<sup>1</sup>The Material Handling Equipment Catalog was developed as part of the Ship Producibility Program by Ingalls Shipbuilding, MARAD Contract 1-36200.

### **6. 3.1 Steel Plate Material Handling Equipment**

**For steel plate handling applications, the following types of equipment were compared:**

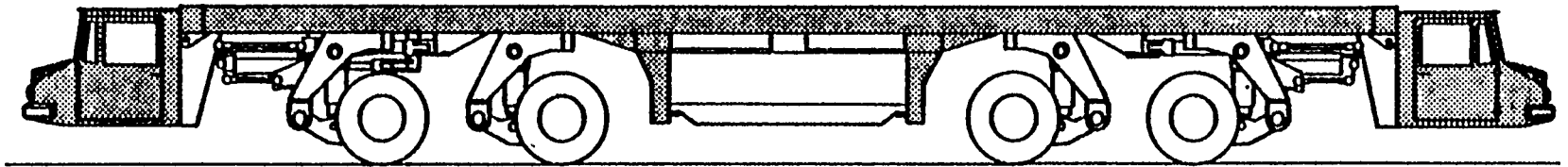
- a. Hydraulic Crane**
- b. Gantry Crane**
- c. Wagon with industrial tractor**
- d. Semi- trailer with truck tractor**
- e. Railroad flatcar**
- f. Straddle- carrier**
- g. Conveyor**
- h. Heavy duty elevating transporter (figures 6-4 and 6-5 )**

**Each of the above types of equipments were compared on the basis of different work volume for movement of steel plate over various distances. The results of these comparisons are shown in figures 6-6 through 6-9.**

### **6.3.2 Material Handling Equipment for Movement of 200-Ton Assemblies**

**In comparing the movement of 200-ton assemblies, three modes of transportation were evaluated:**

- 1. Specialized heavy duty transporter equipped with hydraulic lift and lowering mechanism with capability of lowering or raising structural units from a fixed set of cradles.**
- 2. Whirley crane equipped with a lifting beam and adequate rigging devices.**
- 3. Heavy duty low- level trailer with a truck tractor.**



6-21

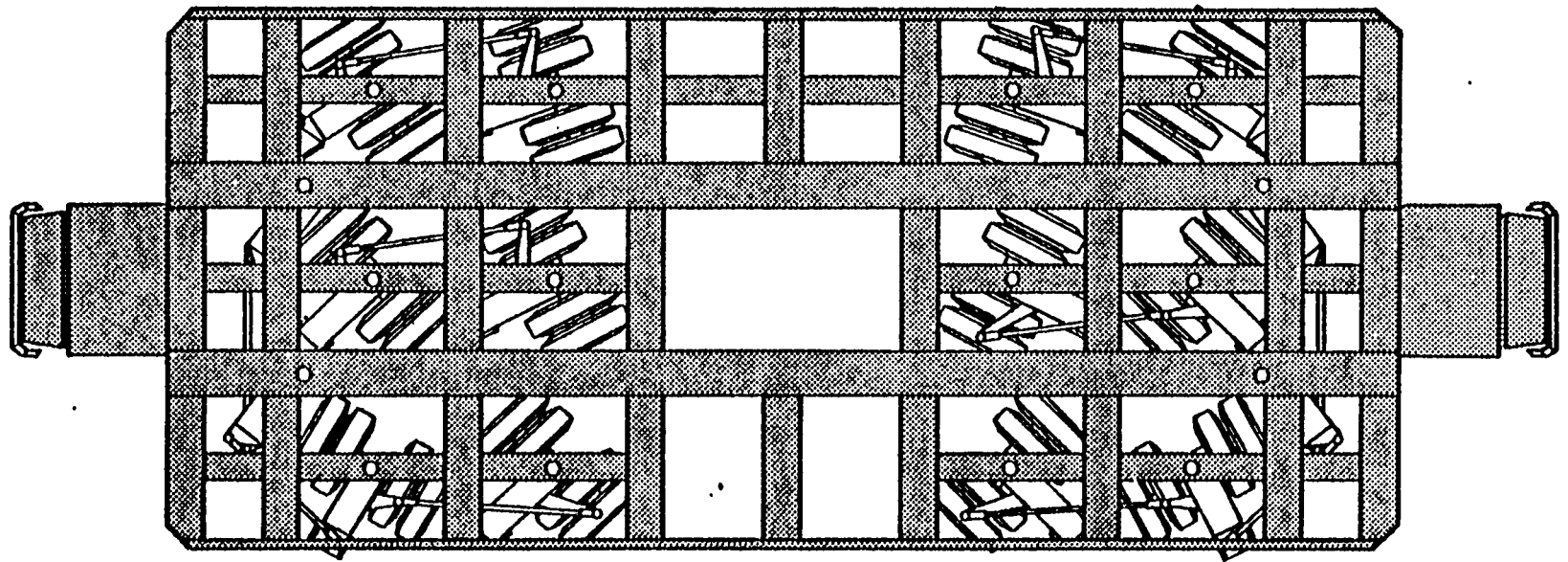


Figure 6-4. Heavy Duty Elevating Transporter

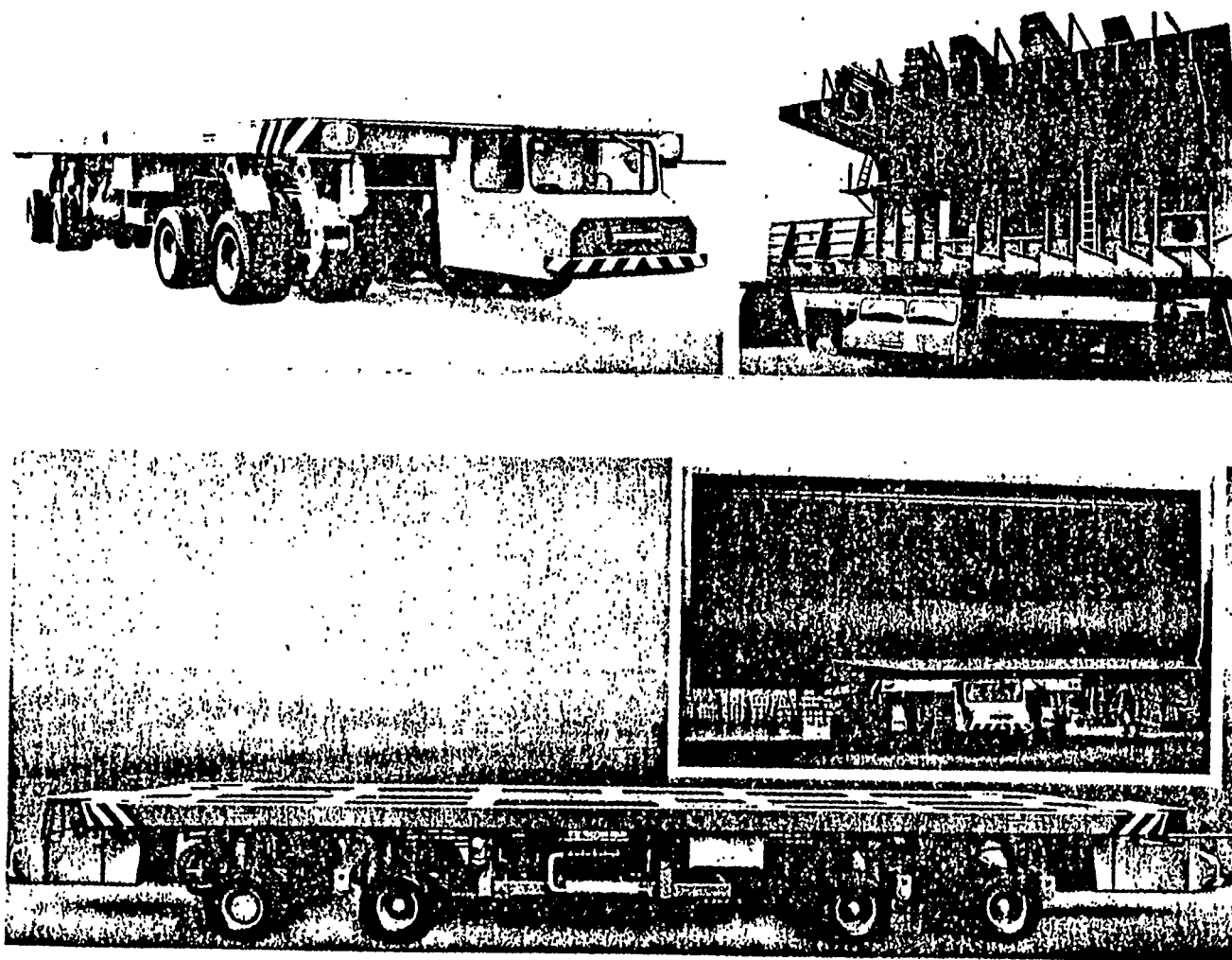


Figure 6-5. Heavy Duty Elevating Transporter

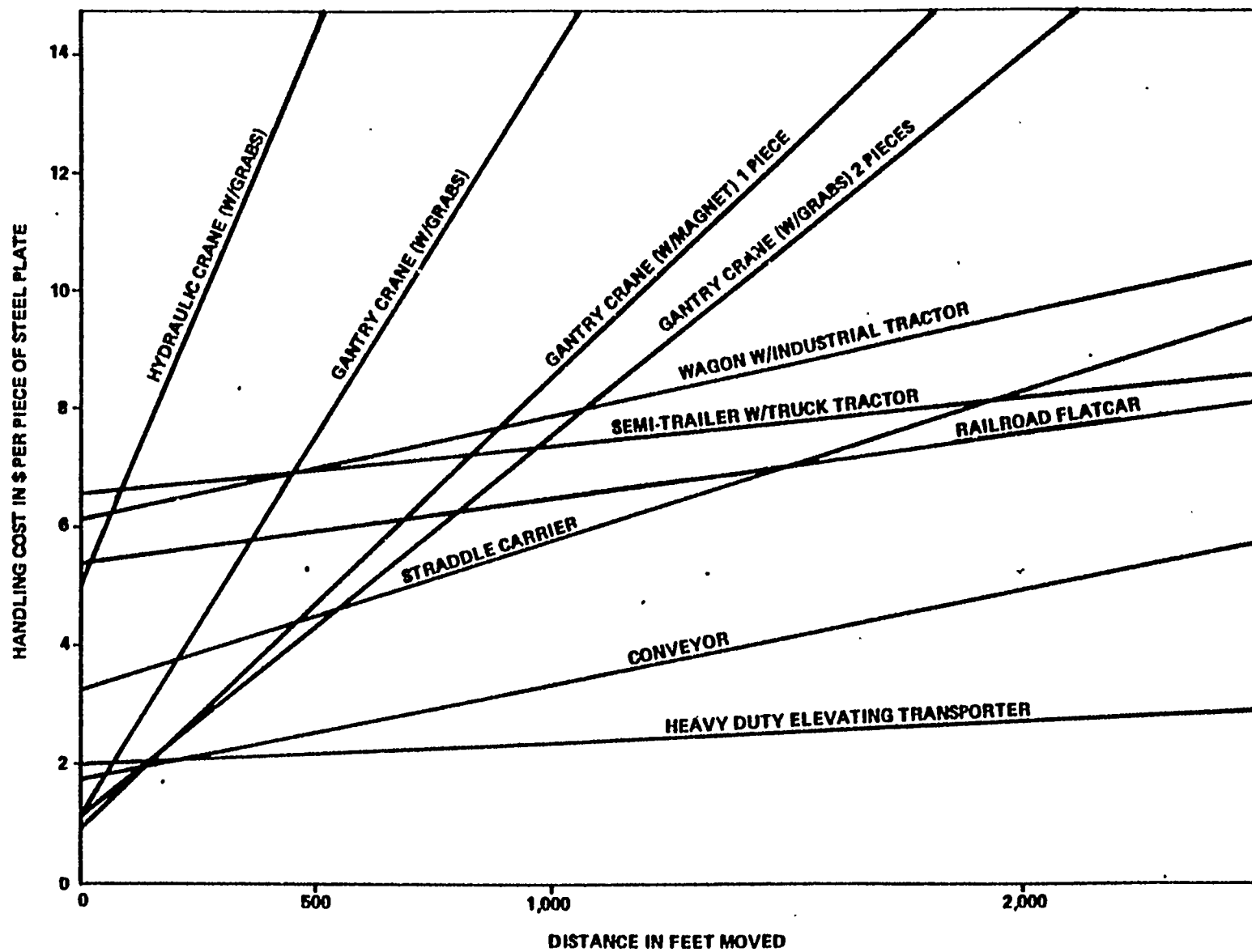


Figure 6-6. Raw Steel Plate Handling Cost Comparison - Single Shift, 1/2 Volume Capacity

6-24

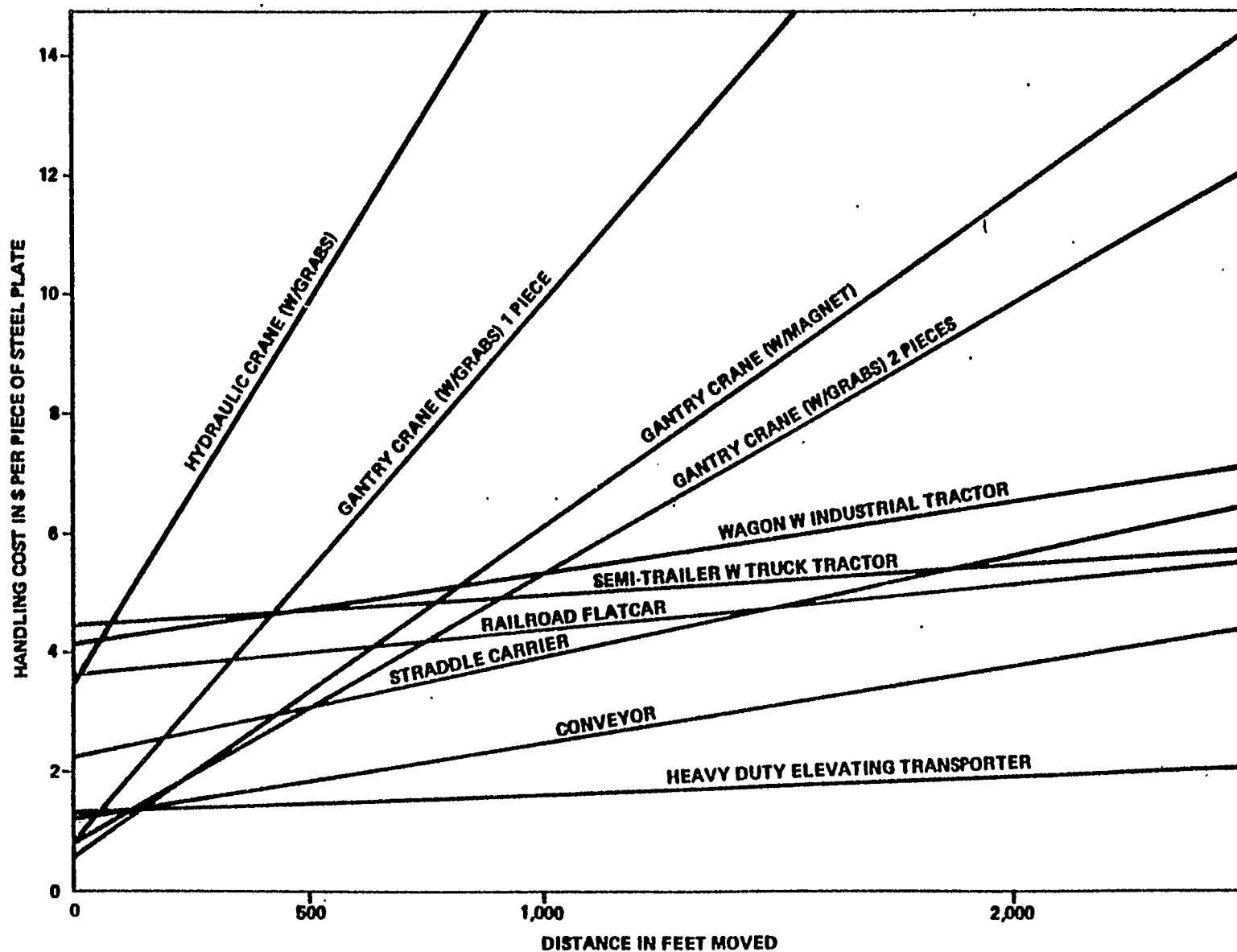


Figure 6-7. Raw Steel Plate Handling Cost Comparison - Single Shift. 3/4 Volume Capacity

6-25

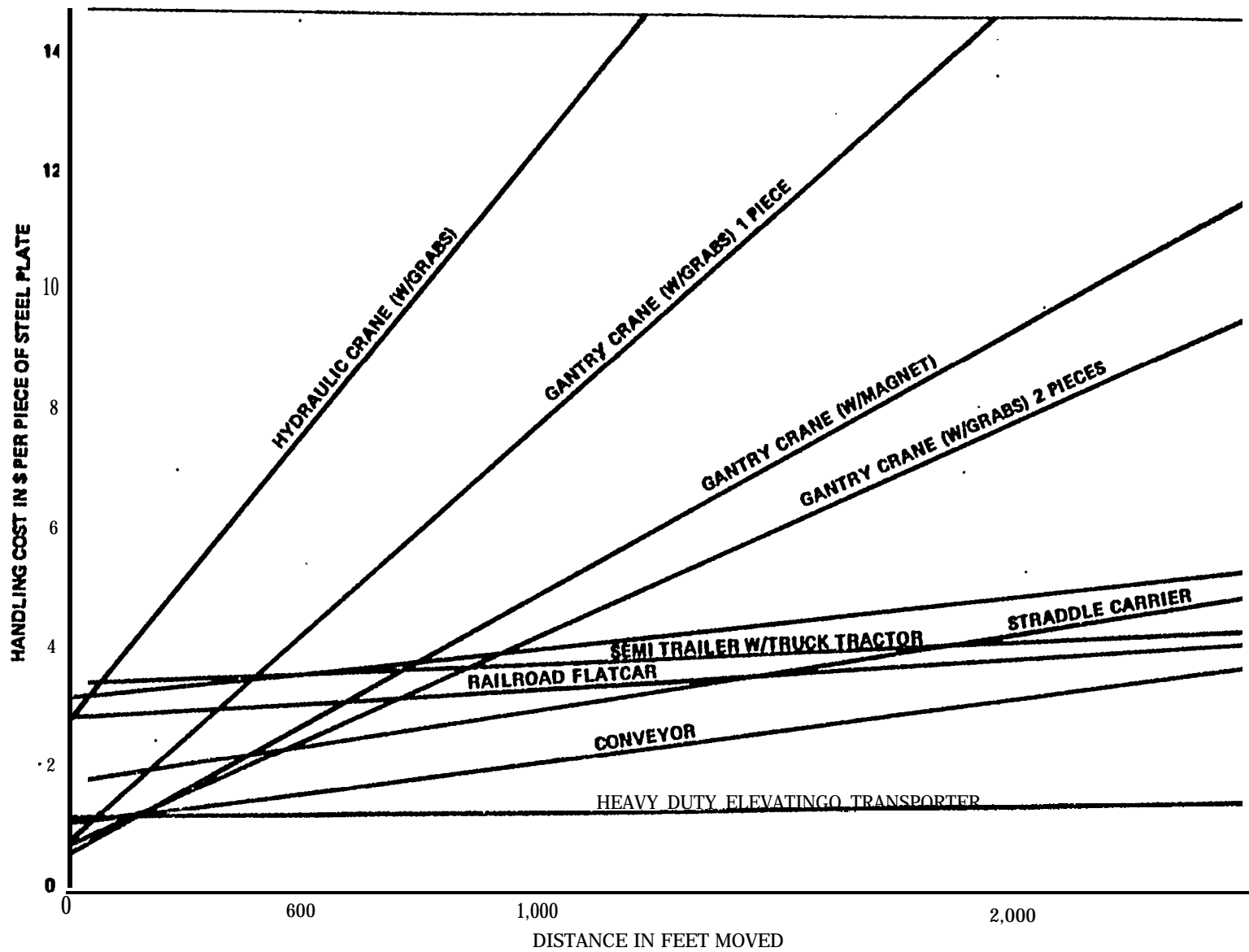


Figure 6-8. Raw Steel Plate Handling Cost Comparison - Single Shift, Full Volume Capacity

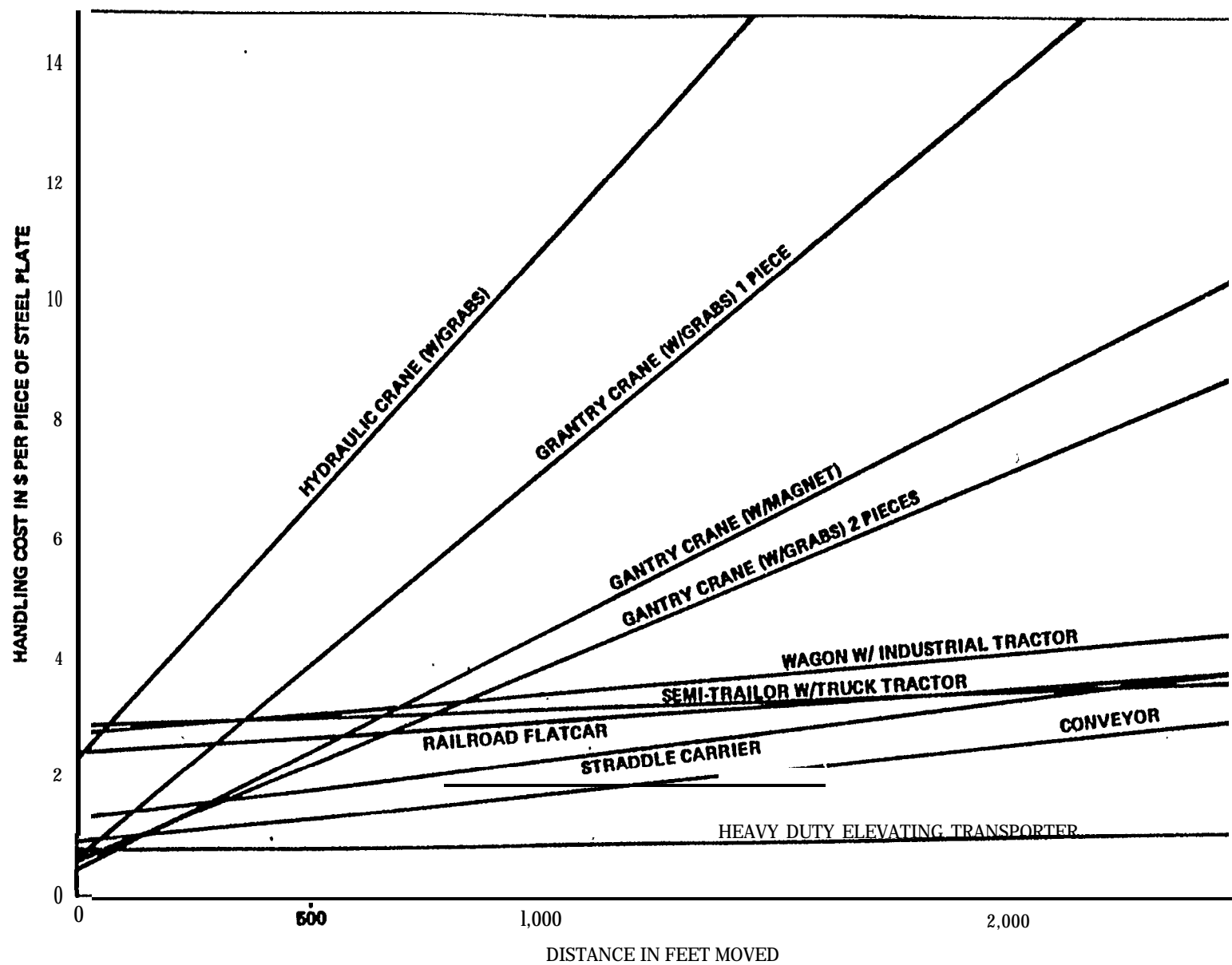


Figure 6-9. Raw Steel Plate Handling Cost Comparison -

Figures 6-10 through 6-13 graphically illustrate the handling cost per 200- ton unit moved for various distances and for each of four different work volumes. Of particular interest is the changeover point in figure 6-12 where the heavy duty trailer and truck tractor become more economical than the whirley crane, for distances in excess of 3/4 of a mile.

### 6. 3.3 Conclusions; Economic Use of Material Handling Equipment

#### Steel Plate Handling

The following is a listing of methods for moving steel plate in the order of desirability.

- a . Heavy duty transporter with self-elevating hydraulic platform
- b. Conveyor (powered)
- c. Straddle carrier
- d. Railroad flatcar
- e. Semi- trailer w/truck tractor
- f. Wagon w/industrial tractor
- g. Gantry crane (w/grabs 2 pieces)
- h. Gantry crane (w/ magnet)
- i. Gantry crane (w/grabs 1 piece)
- j. Hydraulic crane (w/ grabs )

The most economical method of moving plates over a distance exceeding 150 feet, is by heavy duty transporter with self- elevating hydraulic platform (see typical equipment in figures 6-4 and 6-5).

The primary disadvantage of both the conveyor and railroad flatcar is the restriction of movement they may cause to other manufacturing operations. This condition can be minimized by yard layout planning considerations and appropriate directional flow control of material.

6-28

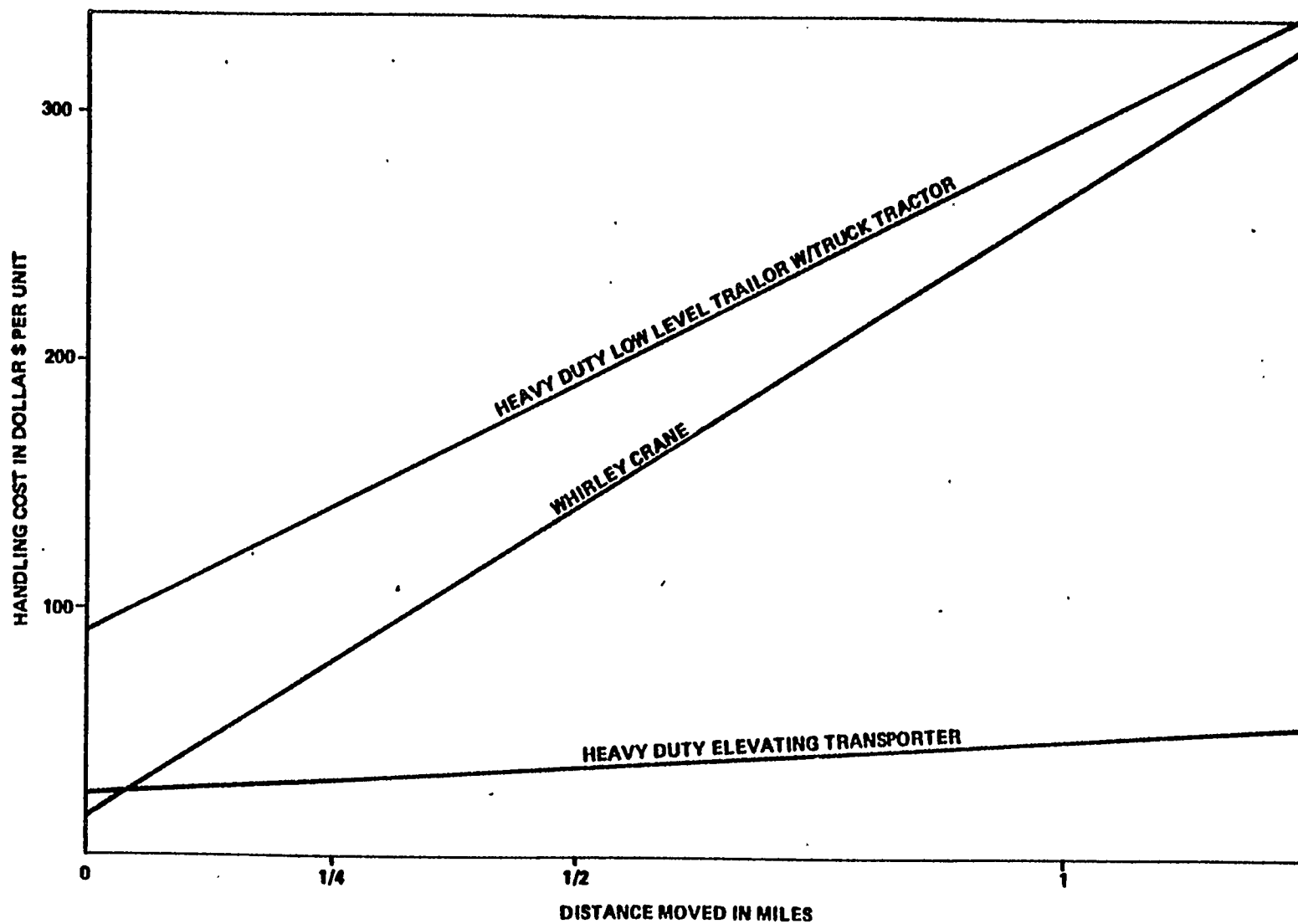


Figure 6-10. Cost Comparison for 200-Ton Load 30- X 60- Foot Platform, Single Shift 1/2 Volume Capacity

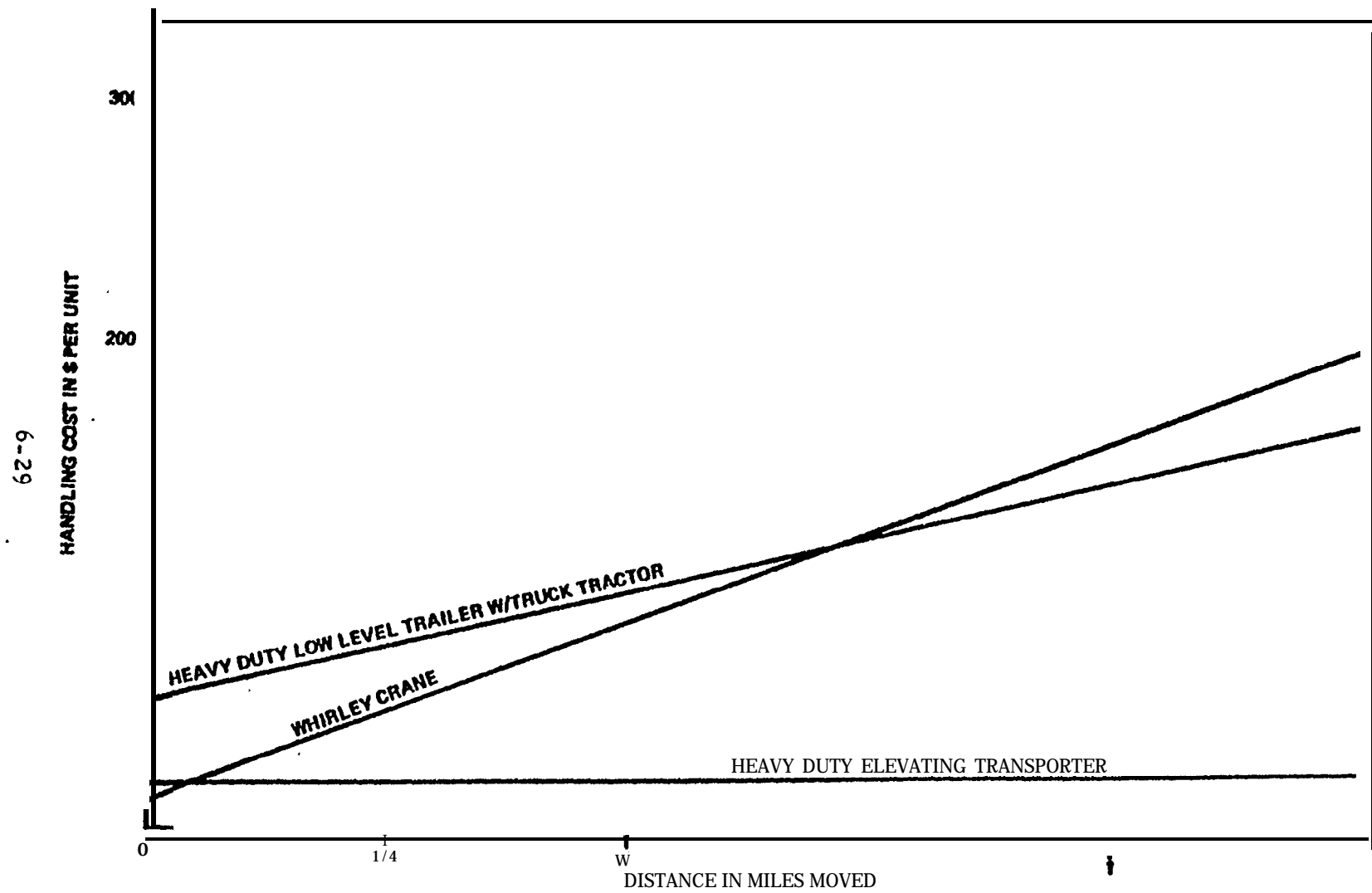


Figure 6-11. Cost Comparison for 200- Ton Load 30- X 60- Foot Platform,  
Single Shift 3/4 Volume Capacity

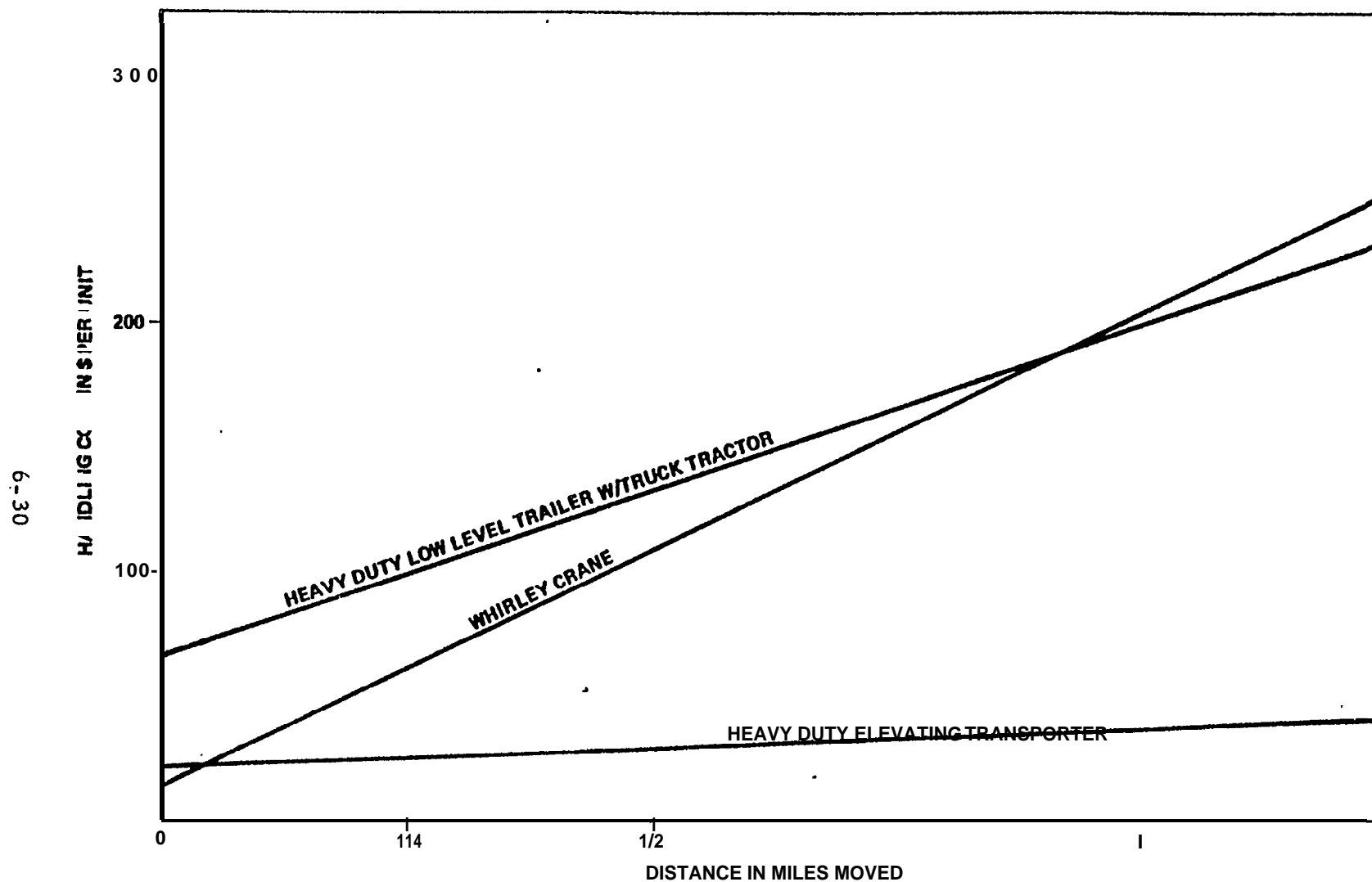


Figure 6.12. Cost Comparison for 200-Ton Load 30- X 60- Foot Platform,  
Single Shift Full Volume Capacity

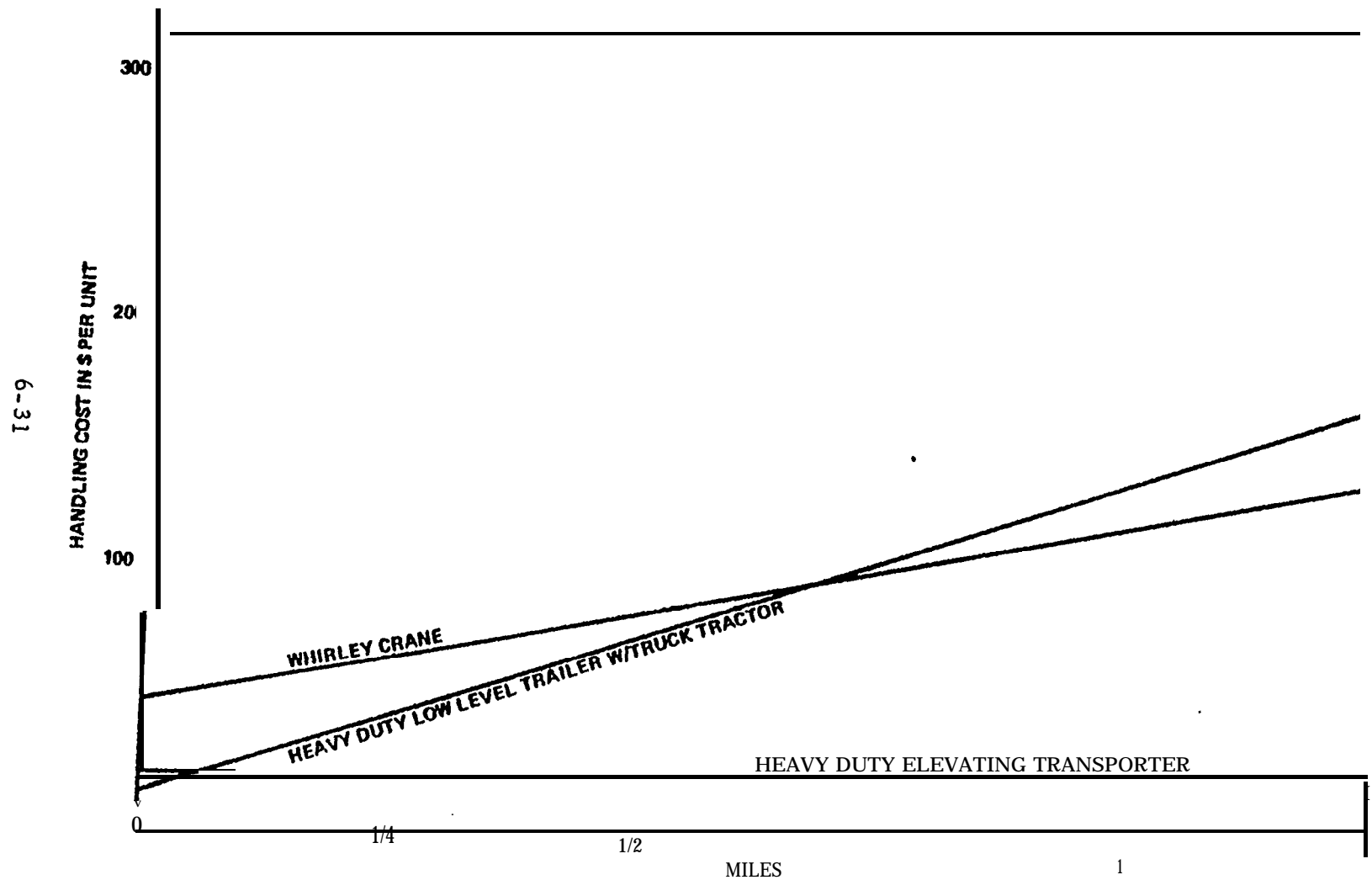


Figure 6-13. Cost Comparison for 200. Ton Load 30- X60- Fool Platform,  
Double Shift Full Volume Capacity

## Movement of 200-Ton Assemblies

The methods used for comparison in moving 200-ton assemblies are listed below in the order of desirability.

- a. Heavy duty transporter with self-elevating hydraulic platform
- b. Whirley crane
- c. Semi-trailer w/truck tractor

The most economical method of moving 200-ton assemblies is by heavy duty transporter vehicle with self-elevating hydraulic platform.

The advantages of the transporter with self-elevating hydraulic platform are:

- a. Minimal operating cost
- b. Self-propelled, self-elevating
- c. Loads and unloads from pedestals
- d. Extremely maneuverable, all wheels steer, and controls are provided on each end.

The disadvantages of the transporter with self-elevating hydraulic platform are:

- a. Comparatively high initial cost
- b. Hydraulic systems require a high degree of preventive maintenance.

#### 6.4I HEAVY LOAD MOVING SYSTEMS

Several moving systems other than cranes have been developed in recent years by means of which structures ranging from 400 tons to thousands of tons may be moved horizontally for distances commensurate with shipbuilding requirements for assembly, integration and launch. For purposes of this study three U. S. manufacturers of such equipment were visited. Summarized findings are presented below:

##### 6.4.1 Hydranautics

Hydranautics of Goleta, California, produces three mechanical heavy load moving systems, two for horizontal transfer movement and one for hoisting or lowering. All three units use hydraulic jacks for powered movement of loads and for directional control. Each unit requires a comparatively low capital investment and is deigned to provide maximum flexibility of use. However, each installation should be custom designed to suit the specific needs of the shipyard.

##### a. Gripper Jack System

The Hydranautics gripper. jack is a tool for applying very large traction forces to transfer a ship, or module structure horizontally (figure 6- 14). The two basic elements are the hydraulic gripper and the jacking cylinder. The jacking cylinder provides the traction force which moves the load. The load normally rests on two or more sliding timbers which travel on lubricated skidways. In a typical application the load slides on the upper cap of an H beam while the grippers clamp in pairs on the two sides of the cap. The grippers are hydraulically locked for the push stroke but slide freely during the retraction stroke of the cylinders.

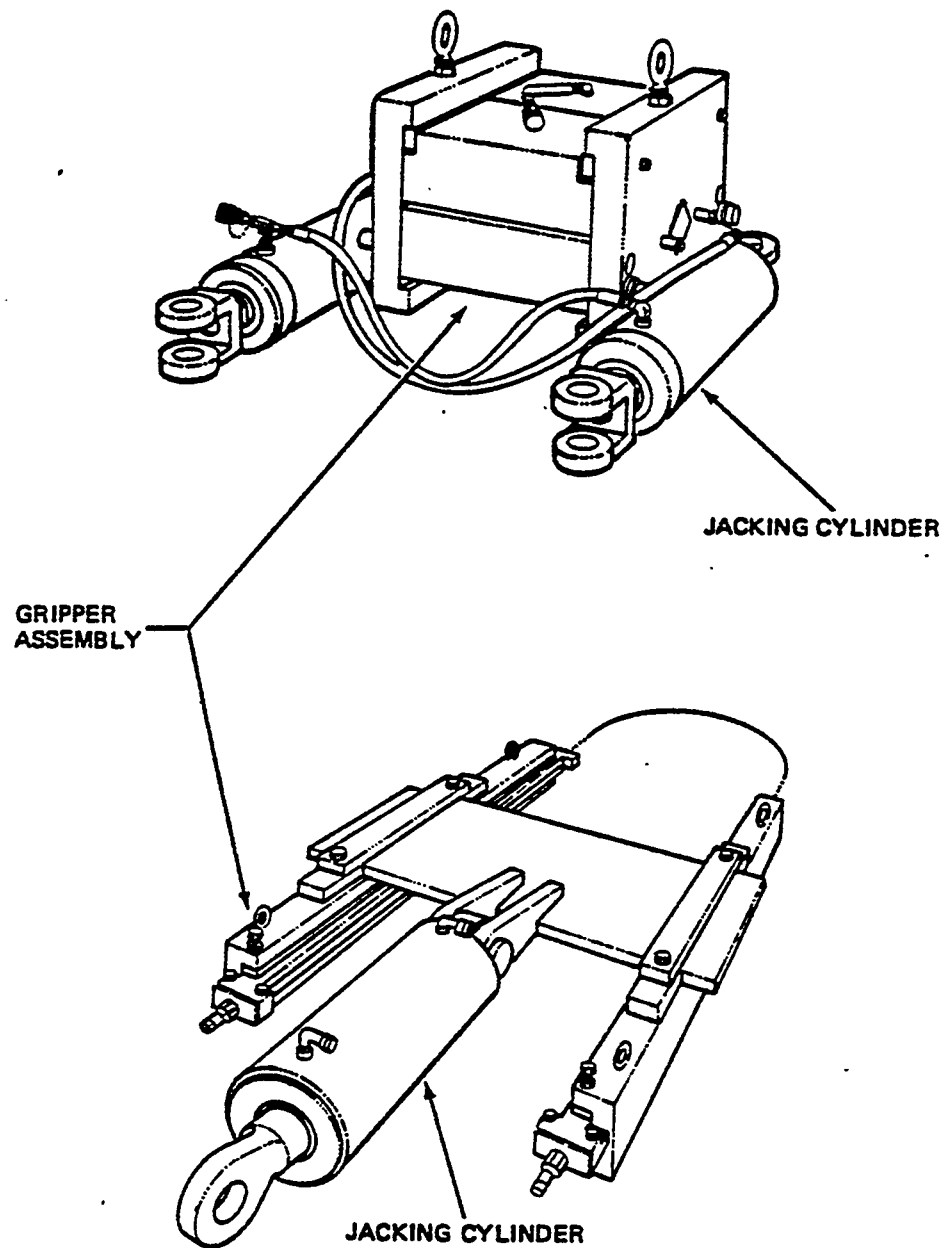


Figure 6-14. Gripper Jack System

The move cycle is lock, push, unlock, retract. Movement of the load occurs in increments of one jack stroke per cycle to achieve rates of travel up to forty inches per minute. Gripper clamping forces are applied hydraulically without force-multiplying linkages and are designed to exceed the jacking forces by a factor of two. For example, grippers totaling 2,000 tons of clamp force may be used to move a 1,000 ton load. Figure 6-15 shows the operating principle of the gripper-jack. Figure 6-16 shows a gripper jack system being used to move a ship section from its construction ways into a floating drydock. Gripper jacks have been developed in a variety of sizes and configurations. Capacities of individual jacking assemblies range from 20 tons to 750 tons. Multiple jack systems have been manufactured to provide a combined thrust of several thousand tons on a single load. These systems move ships or ship sections weighing up to 15,000 tons. Systems have been produced using multiple jacks and single or multiple power supply units to suit a wide variety of applications, such as:

- ( 1 ) Bidirectional moving of ship sections and barges
- (2) Moving stern modules for tandem construction
- (3) Moving 15,000 ton ship mid-body modules from ground ways to launch platform.

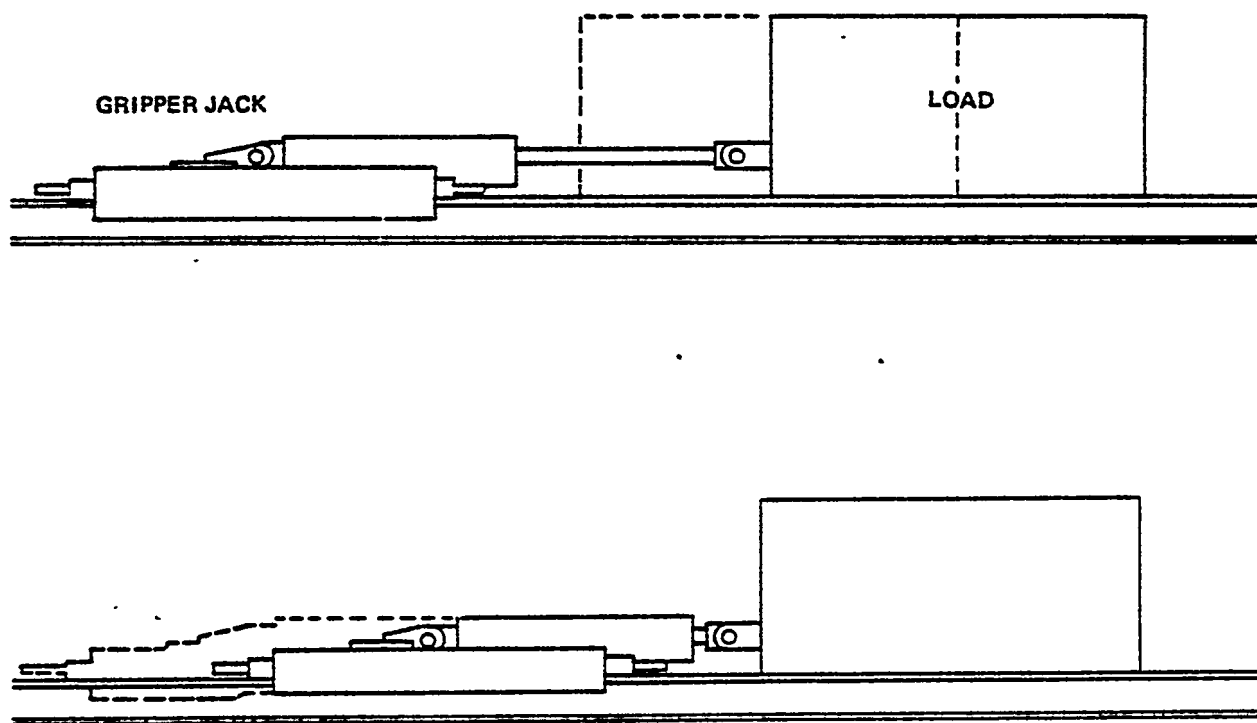


Figure 6-15. Gripper Jack Principle

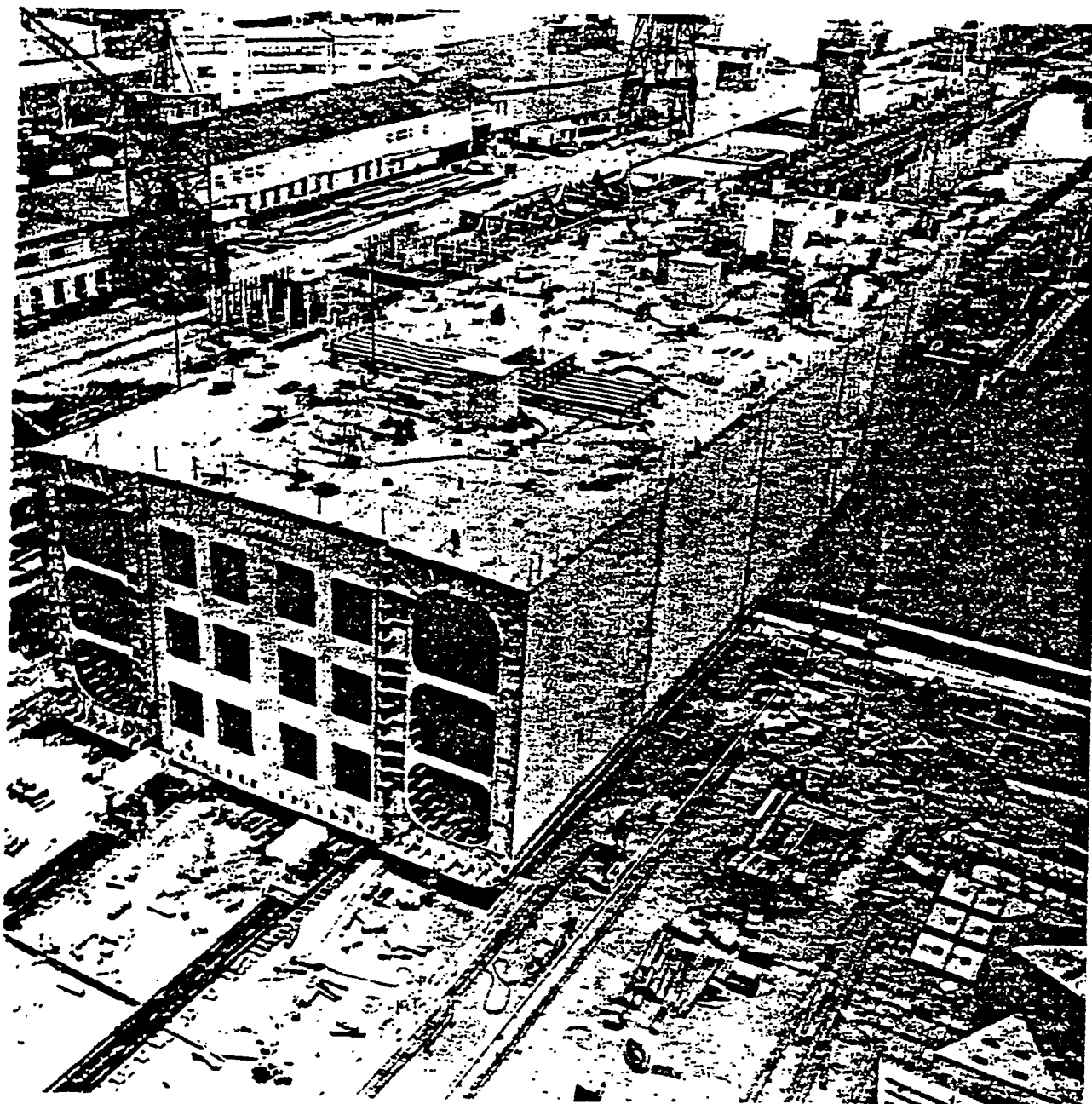


Figure 6-16. Gripper Jack Application

## b . Hydraulic Translift

The Hydranautics trans-lift hydraulically transports its load without the need for extensive rail or road systems or the need for applying external traction forces to the load itself or to the supporting surface. The trans - lift is designed to distribute the load over a large bearing area, so that the civil costs associated with transporting ultra-heavy loads may be reduced. The trans-lift is comprised of four basic components (see figure 6- 17): lift jacks, transfer jacks, a static structure and a sliding structure. Combined with the above components, low friction, teflon plate bearings act as slip joints between the static and the sliding structures. Trans-lifts may be uni or multi-directional. Hydraulic pressures range up to 5000 PSI. The 3000 ton trans-lift unit is shown in figure 6-18 in a 12, 000 ton system application.

The system transports its load with a "walking" motion. The operating sequence of a trans-lift is illustrated in figure 6-17. The four steps are explained below.

- (1) Lift cylinders extend, lifting the static support structure off the ground, in turn lifting the load. Lifting transfers the load to the sliding structure which now has ground contact.
- (2) Transfer jacks extend, producing a relatively horizontal movement between static structure and sliding structure. The load is advanced a distance of one jack stroke.

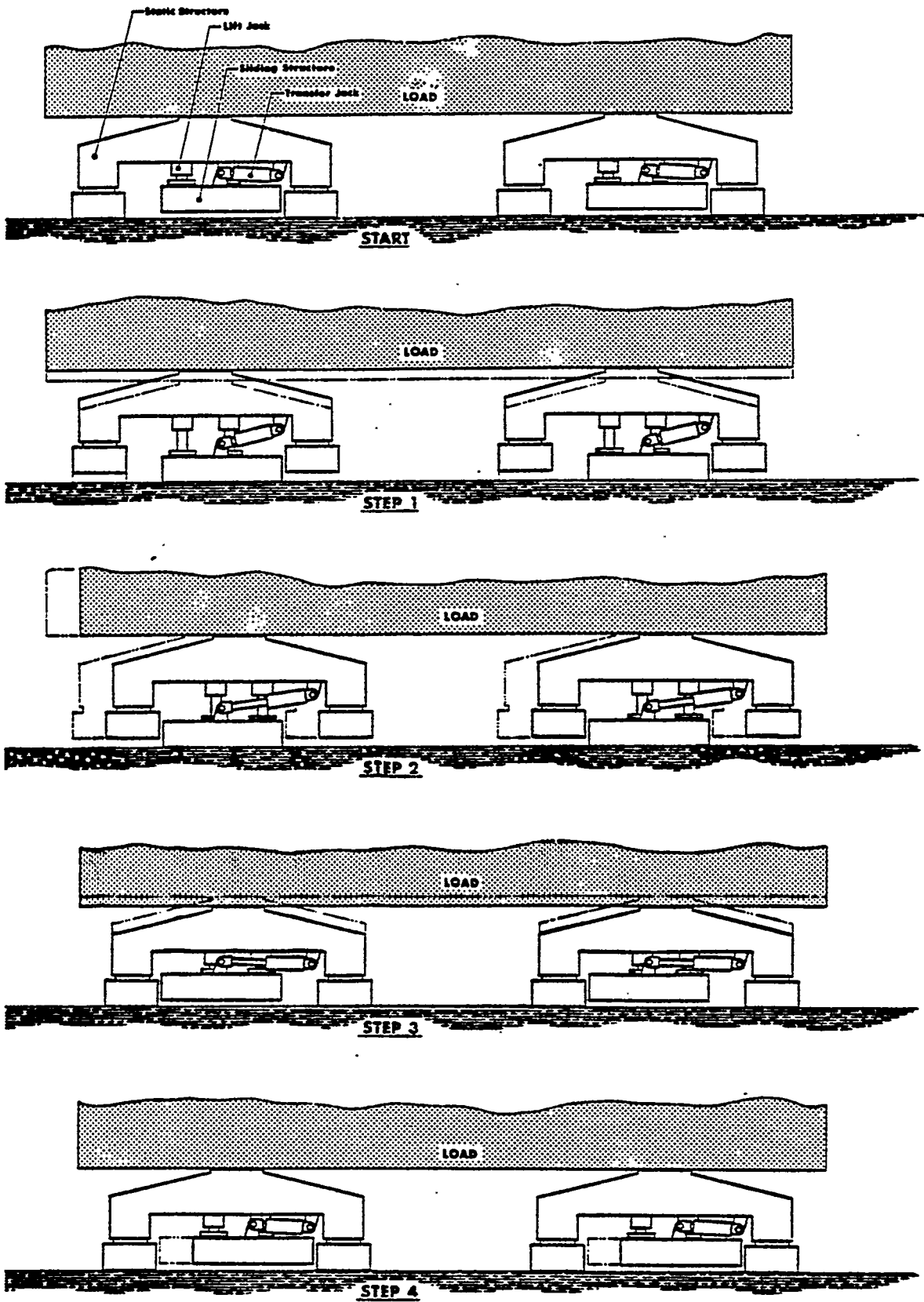


Figure 6-17. Translift Function Sequence

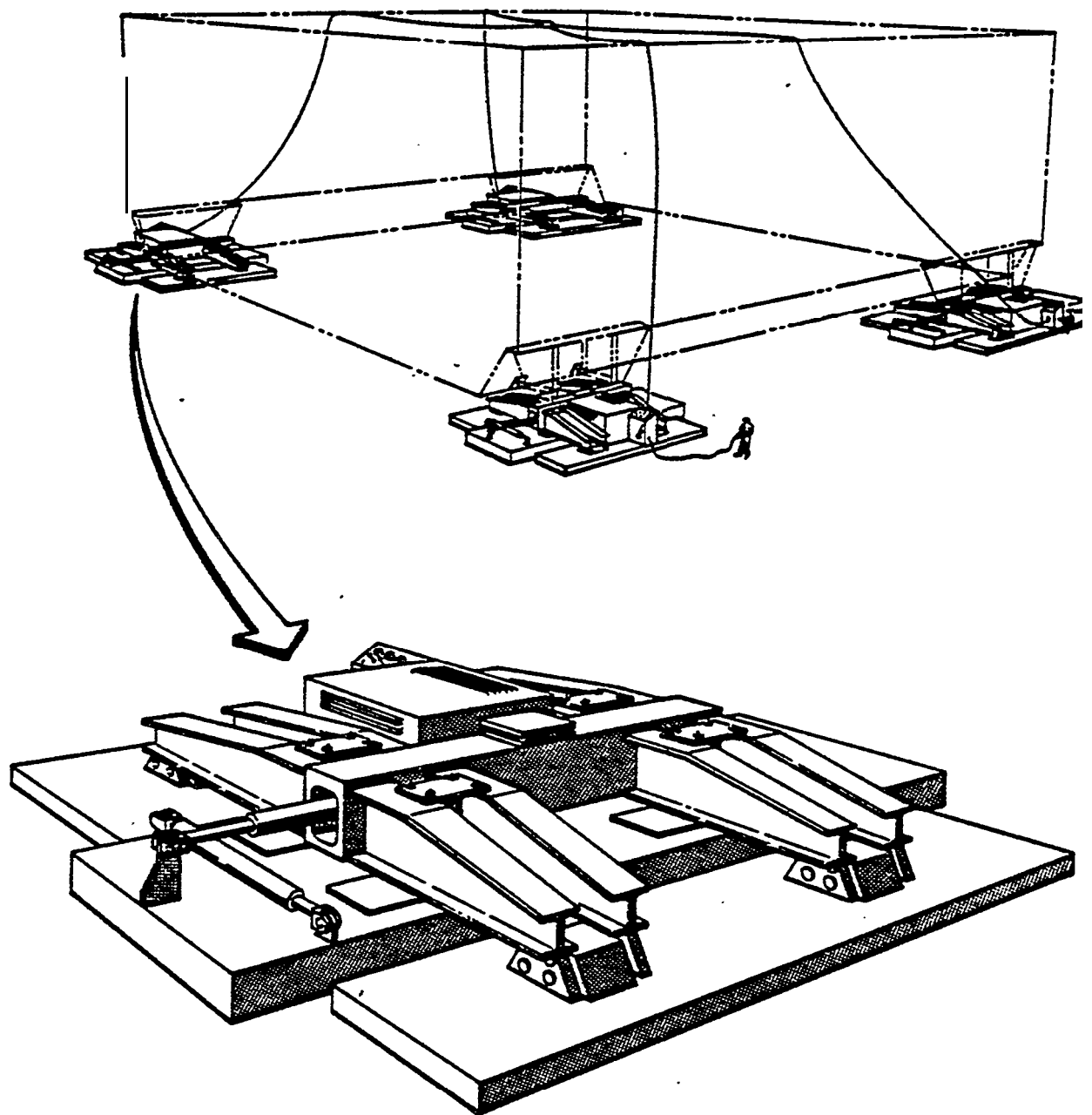


Figure 6.18. 3000 Ton Translift Unit and System Application

- (3) Lift cylinders retract, lowering the static structure until it contacts the ground. Lift cylinders continue retracting until sliding structure is lifted off the ground.
- (4) Transfer jacks retract, in turn shifting the sliding structures to its original position. The above describes the required motions for a single trans - lift moving in a straight line. Translifts and mating control systems are available to provide lateral, longitudinal, and rotational moves.

The system - A complete trans-lift system consists of one or more translift units and a hydraulic power pack. The power pack may be externally powered or may have a self-contained diesel or gasoline drive.

Applications - Trans-lift systems can be used in many applications where loads in the several hundred, or several thousand, ton range must be transported. Examples of current trans-lift uses include:

- (1) Series production of ships, barges and offshore oil rigs.
- (2) Loading or unloading multi-ton ship assemblies on or off barges.
- (3) Movement of ship stern modules from assembly/erection position to integration and/or launch position.
- (4) Translation of pre-fabricated LNG tanks from building position to installation position.

Cost -. The budgetary cost of the trans-lift system is \$60.00 per ton of lift/move capacity.

### C. Hollow Ram Chain Jack

The hollow ram chain jack is a unique combination of hydraulic and hydro - mechanical linkage interconnected to produce a versatile mechanism for lifting or moving heavy loads. Consisting of a hollow ram hydraulic cylinder with chain engagement latches on the outer cylinder base and on the rod end, (see figure 6-20) the chain jack can pull or climb chain, depending on the operation desired. The chain jack can be used singly. or in groups all controlled from a central power/control unit.

Method of Operation - The hollow ram chain jack is operated by alternately transferring the loaded chain from the cylinder latch mechanism to the ram latch mechanism while stroking the hollow ram to haul in, or pay out chain. Models are available with either manual latch positioning or hydraulic latch positioning. Stroke length of the jack is slightly greater than the chain pitch. By alternately extending and retracting the rams with hydraulic pressure, while synchronizing the latches, the mechanism moves the loaded chain. Alternatively the chain jack may be used to advance the load along a stationary chain. The load is sequentially supported by one latch and then the other. One latch cannot be disengaged unless the other latch is supporting the load.

Advantages - The hollow ram chain jack system can replace more expensive rotating machinery for many applications. Minimum operator skill is required, equivalent to that required for operation of any heavy duty type hydraulic jack. Chain jacks may be furnished to operate from the user's hydraulic power supply by addition of suitable controls.

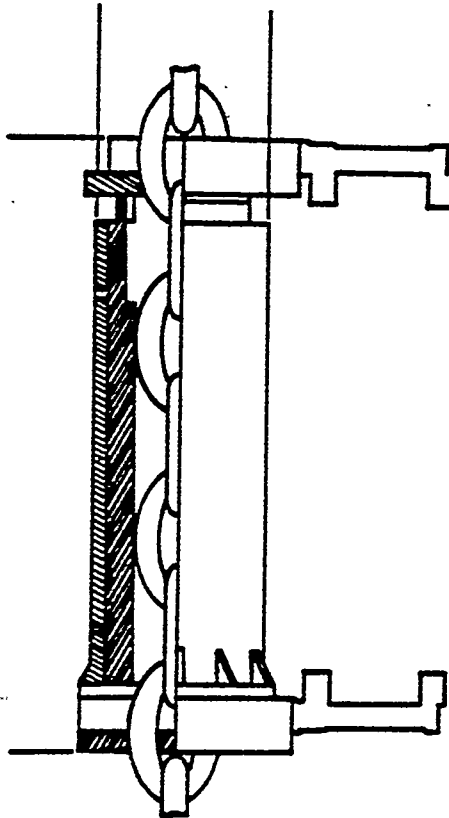
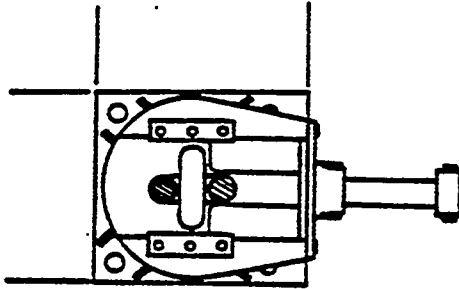


Figure 6-19. Hollow Ram Chain Jack

Chain Jack Systems - Hydranautics furnishes complete pulling or lifting systems employing the standard chain jack as the basic load moving component. A simple system consists of a single chain jack and an operating station which combines the hydraulic power source, control console and hose assemblies for interconnecting the operator station with the chain jack. More complex systems employ multiple chain jacks, powered and controlled from one or more operator stations. There are many variations to the system such as unidirectional travel, bi-directional travel, and synchronized travel of multiple units.

Applications - Chain jacks are in use in shipbuilding and heavy construction applications. Chain jacks are used to replace any device using chain to lift heavy loads precisely and economically.

d. Hydraulic Power Pack

The hydraulic power pack is the control unit for any of the three Hydranautics systems described in preceding paragraphs.

Circuitry varies from one application to another and size varies with horsepower and type of prime mover. A typical unit uses an iso-flow pump for controlling multiple jacks at matched stroke speeds. Accurately matched flows can be directed to two or more jacks regardless of load differentials.

As many as fourteen jacks can be driven from a single pump. Differential speeds between jacks can also be produced to advance a load along a curved track.

#### 6.4.2 Rolair Systems Inc.

The Rolair Company is engaged in the design, development and manufacture of heavy lift and move equipment utilizing a fluid film system for lift and frictionless movement of very heavy loads.

The primary users of this equipment are shipbuilders and offshore oil companies as well as non-marine heavy industries.

##### a. Airlift Transporter

The Airlift Transporter is a heavy load (500-ton) moving device manufactured by Rolair Systems, Inc. , of Santa Barbara, California, (see figure 6-20). The transporter levitates its load on fluid cushions formed between the under side of the transporter frame and the pavement or other hard, smooth, supporting surface. This permits nearly frictionless translational or rotational movements of very heavy loads by means of externally applied thrust and control. Higher capacities are attained using multiple arrays of the basic cushion unit. This unit or bearing delivers a regulated flow of water or air from inlets on the transporter frame to a urethane bladder or diaphragm which under operating pressures makes a donut shaped cushion. The contour of the diaphragm is such that under working pressures it entraps fluid in a circular cavity then applies pressure to the entrapped fluid thereby lifting the load. The escaping of the fluid between the diaphragm and the supporting surface isolates the load from contact with the ground on a nearly frictionless fluid film. The lift capacity of a particular array will be the product of the cushion areas of one bearing unit times the number of units times a fluid pressure factor. Of the family of airlift

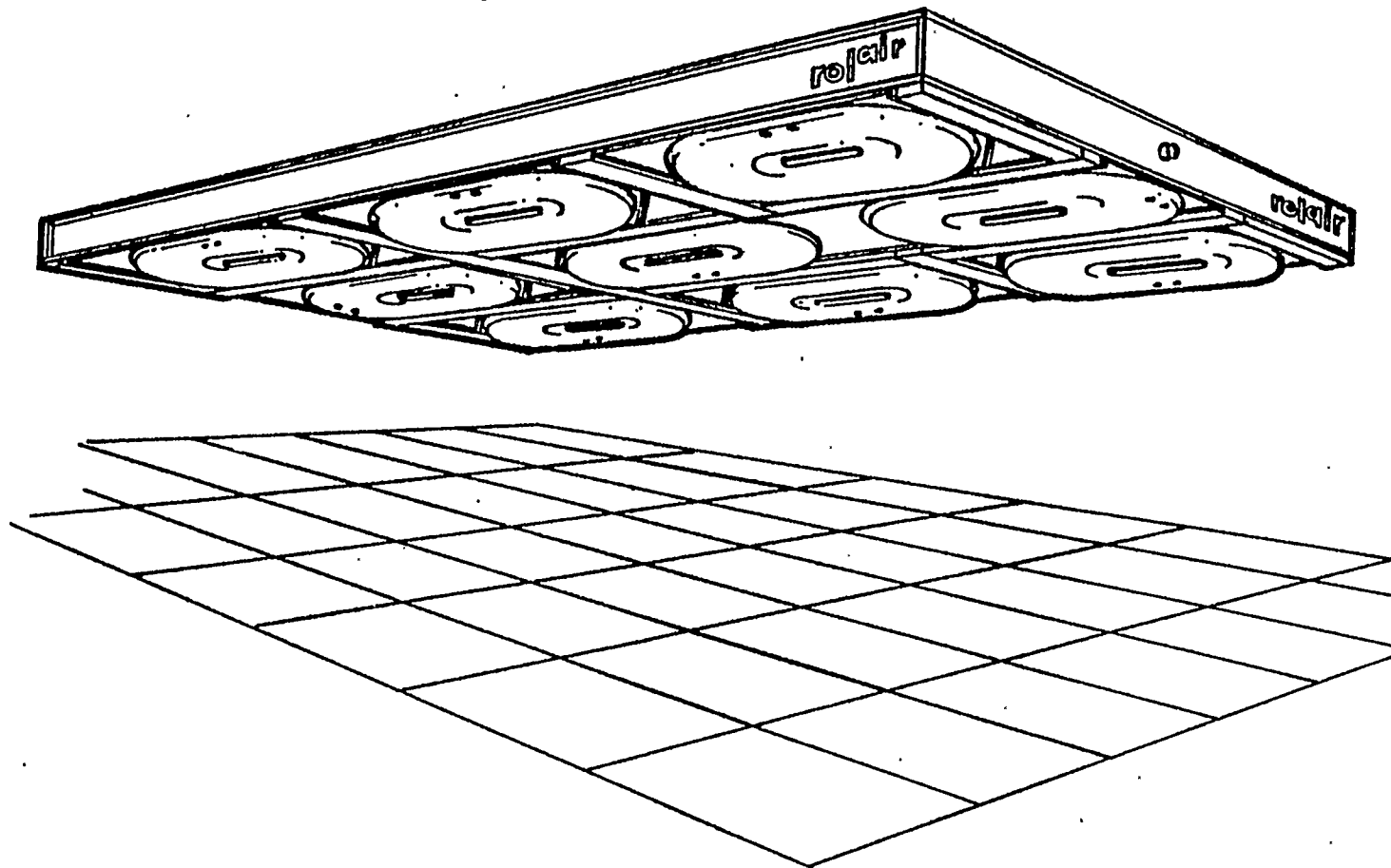


Figure 6-20. Airlift Transporter, 500-Ton Capacity

transporters the 500-ton capacity unit shown in figure 6-20 is the most widely used in shipbuilding.. The unit is a box type support structure of heavy duty steel beams, channels and plates with a minimum dimension of twelve feet wide by eighteen feet long by twelve inches high. A 500 ton payload (dimensions permitting ) can be supported by one transporter.

Advantages of the Airlift Transporter are no moving parts, simplicity of operation and low acquisition cost (\$50 to \$60 per ton lifting capacity in normal applications). One important consideration in using the Airlift Transporter is its need for a hard, smooth, and level operating surface.

The Rolair approach to movement of ultra large/heavy units does not in most respects represent a significant departure from traditional big load movement systems utilizing wheels, rails, etc. Movement in either case requires the placement of load-carrying modules beneath the payload, an operating surface of some type, and an amount of hardware durability compatible with the fabrication procedures utilized. These three factors are constants.

The Rolair system does, however, offer special major advantages which when properly applied will result in savings. Savings in terms of actual movement labor can be realized by taking full advantage of fluid film's frictionless characteristics. For setup and takedown fewer men are required per size of lift/move than for crane/wheel systems of similar size. Moving speeds can be governed by safety and in most cases will be faster than can be attained with wheeled systems. Secondly, it is felt that because the Rolair hardware has no moving parts,

maintenance problems will be reduced to replacement of worn or damaged diaphragms. The most vulnerable portion of the fluid film unit is the diaphragm which is fabricated of wear- resistant urethane. Diaphragm damage usually results from misuse. Protective measures (floating skirts, wipers and brushes ) can be instituted to greatly reduce misuse problems. For example, - it would be expected that a nine-bearing system for 500 ton load movement 15 times a year would normally require about 20 percent diaphragm replacement if used properly over a two-year period. Replacement diaphragm of a size discussed here currently sell for about \$500 each. Diaphragms may be purchased in advance and stored for future use. Finally, the flexibility provided by fluid film will allow a maximum amount of load maneuverability (for moving, positioning and rotating) and reduced surface loadings. (The quantity of fluid film bearings and the size of steel or concrete operating surface or operating tracks can be varied as required.

System Applications - System applications of the airlift transporter would include the following:

- (1) Loading/unloading multi- ton ship assemblies to or from barges
- (2) Movement of ship sections from assembly/erection position to integration or launch position.

Figures 6-21 and 6-22 show typical shipbuilding applications using the airlift transporter on a flat, concrete assembly area or integration area.

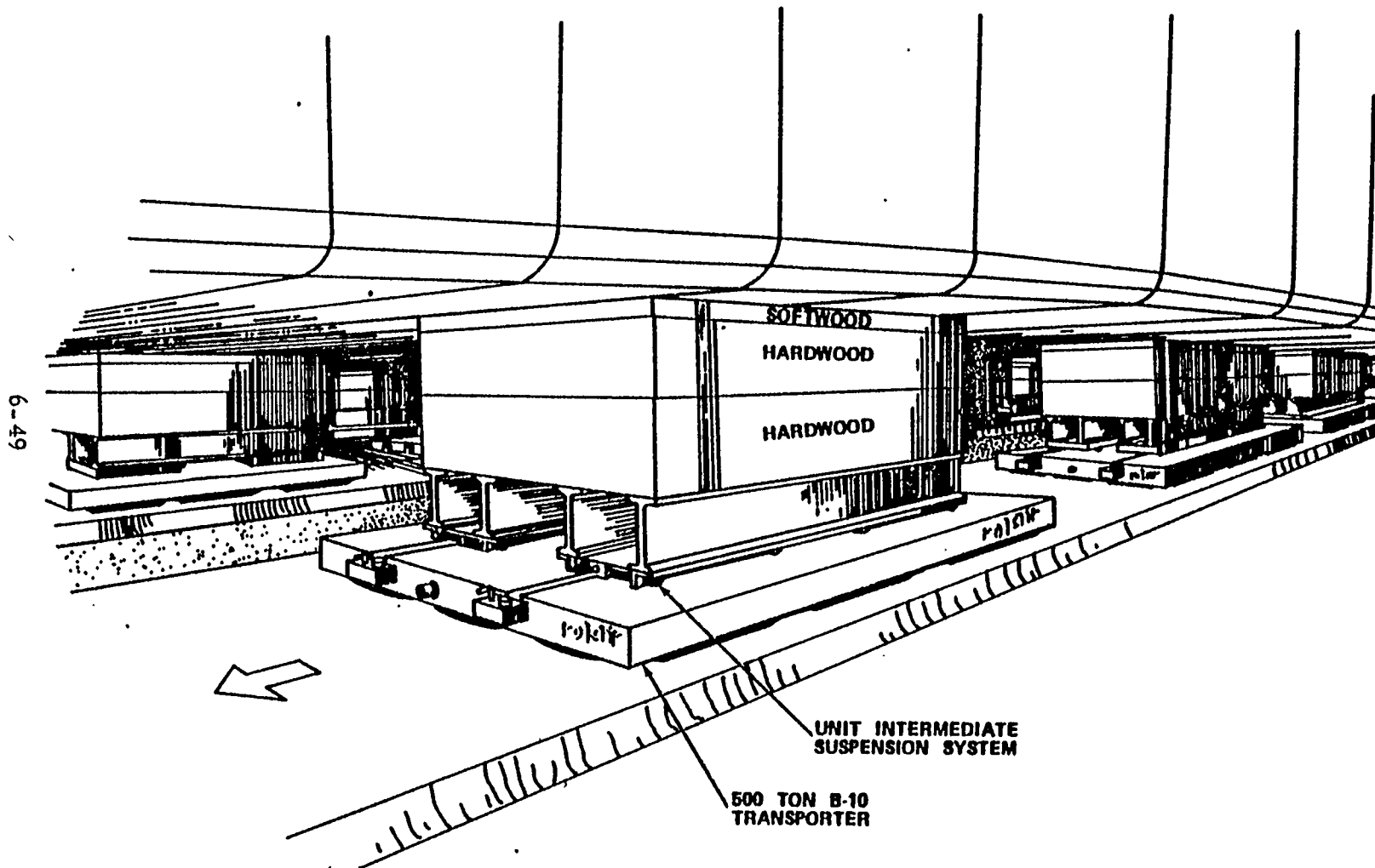


Figure 6-21. Ship Movement Transporter Systems

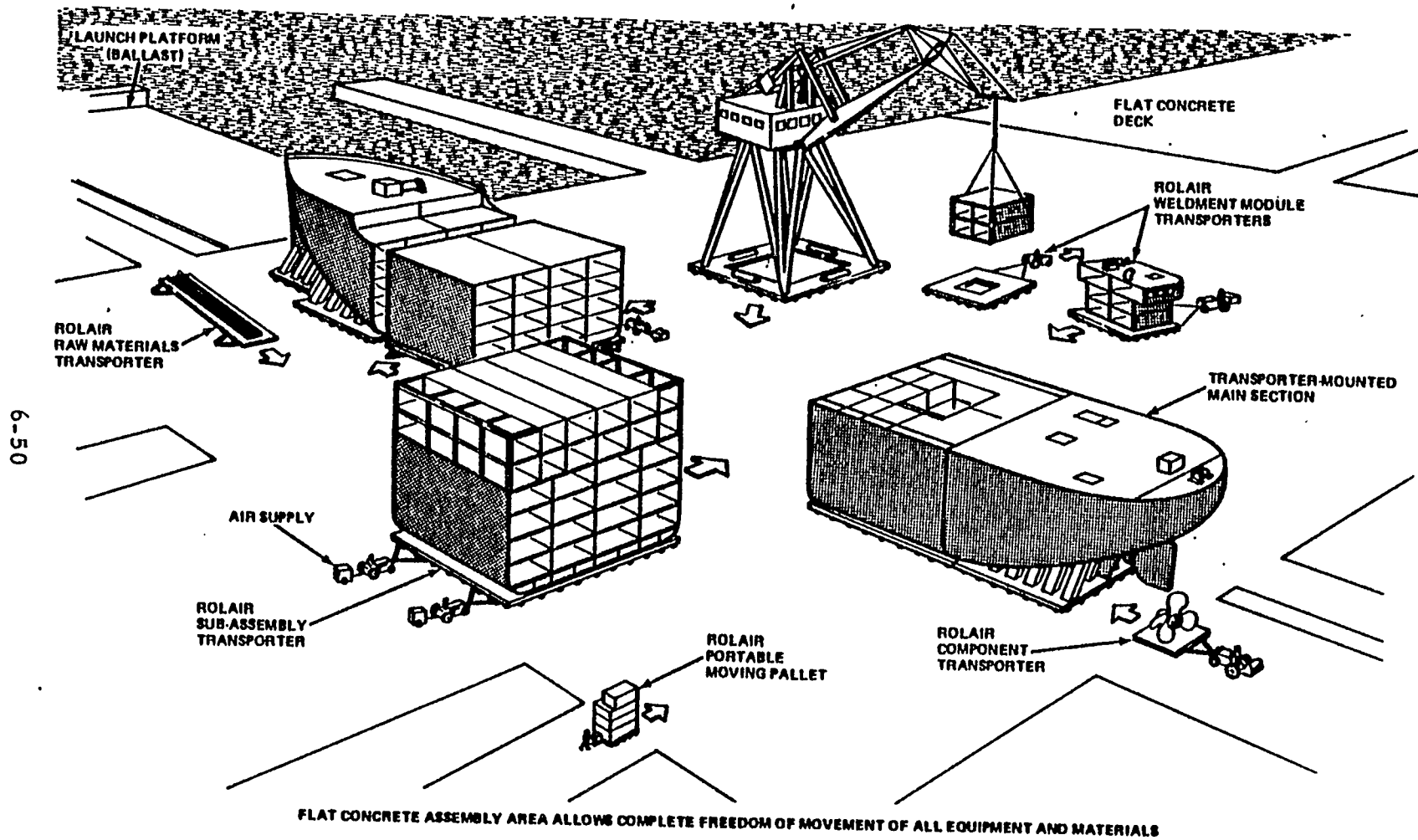


Figure 6-22. Ship Assembly Area Airlift Transporter Applications

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#### 6.4.3 Western Gear, Ship Transfer System

The Western Gear' Ship Transfer System is designed to provide a movable platform on which ship assemblies can be erected and subsequently moved to the integration area. Upon being moved to the integration area the system is also used to align and move the modules together for final assembly and to transfer the completed vessel to an exact position required for launch.

The Ship Transfer System consists of power units (figure 6. 23), pallet cars (figure 6-24), transfer cars (figure 6-25), strongbacks (figure 6- 26) and a rail system (figure 6- 27). The ship module is erected on blocking on a group of strongback assemblies. The strongback assemblies are supported on a series of driven and non-driven pallet cars which are positioned so that power distribution is balanced. The completed ship module is moved in an athwartship direction by means of a self-contained power unit driving the pallet cars along rails. Some of the pallet cars are free-wheeling and serve only as support and truckage. All of the pallet cars are chained to the strongbacks. When the ship module reaches the final assembly area, the transfer cars are run under the strongback assemblies and positioned so that power distribution is balanced. The transfer cars then lift the ship module along with the strongbacks and pallet cars and move the module to an interface point with the adjoining module. After final assembly, the hydraulic actuators on the transfer cars are lowered so that the strongbacks again rest on shims on top of the pallet cars which are engaged. into the athwartship rails. The complete ship is carried by the pallet cards to the launch facility.

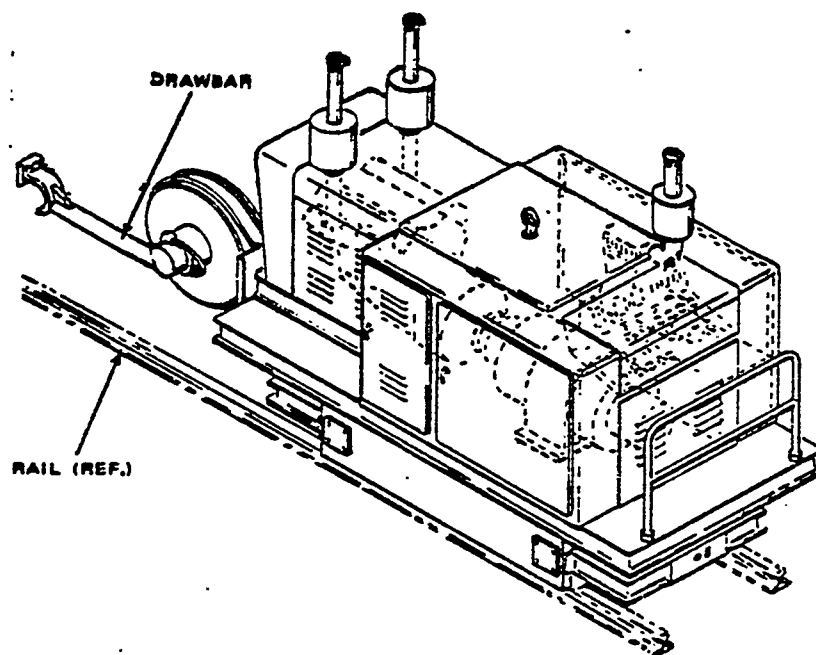


Figure 6-23. Main Power Unit

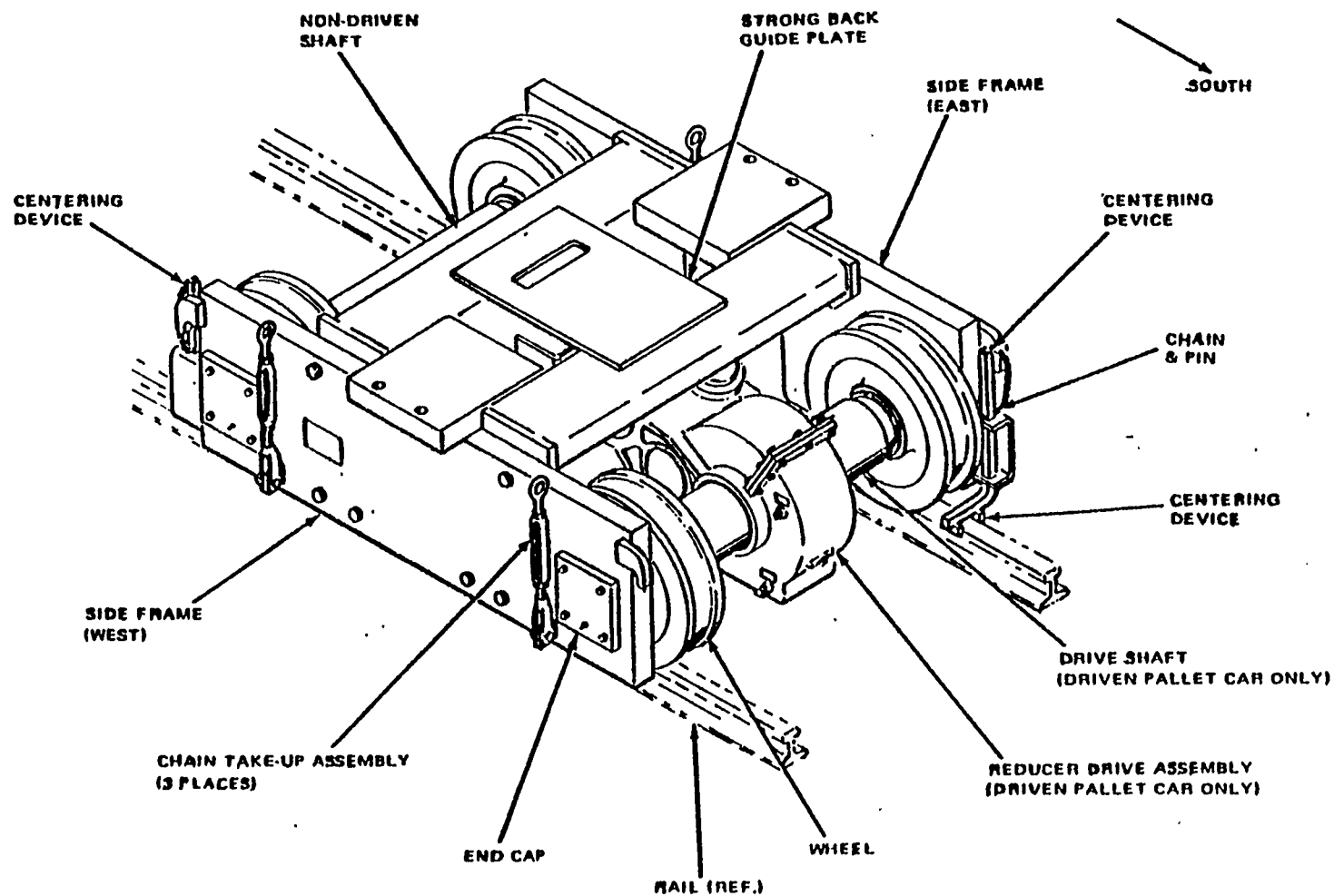


Figure 6-24. Pallet Car

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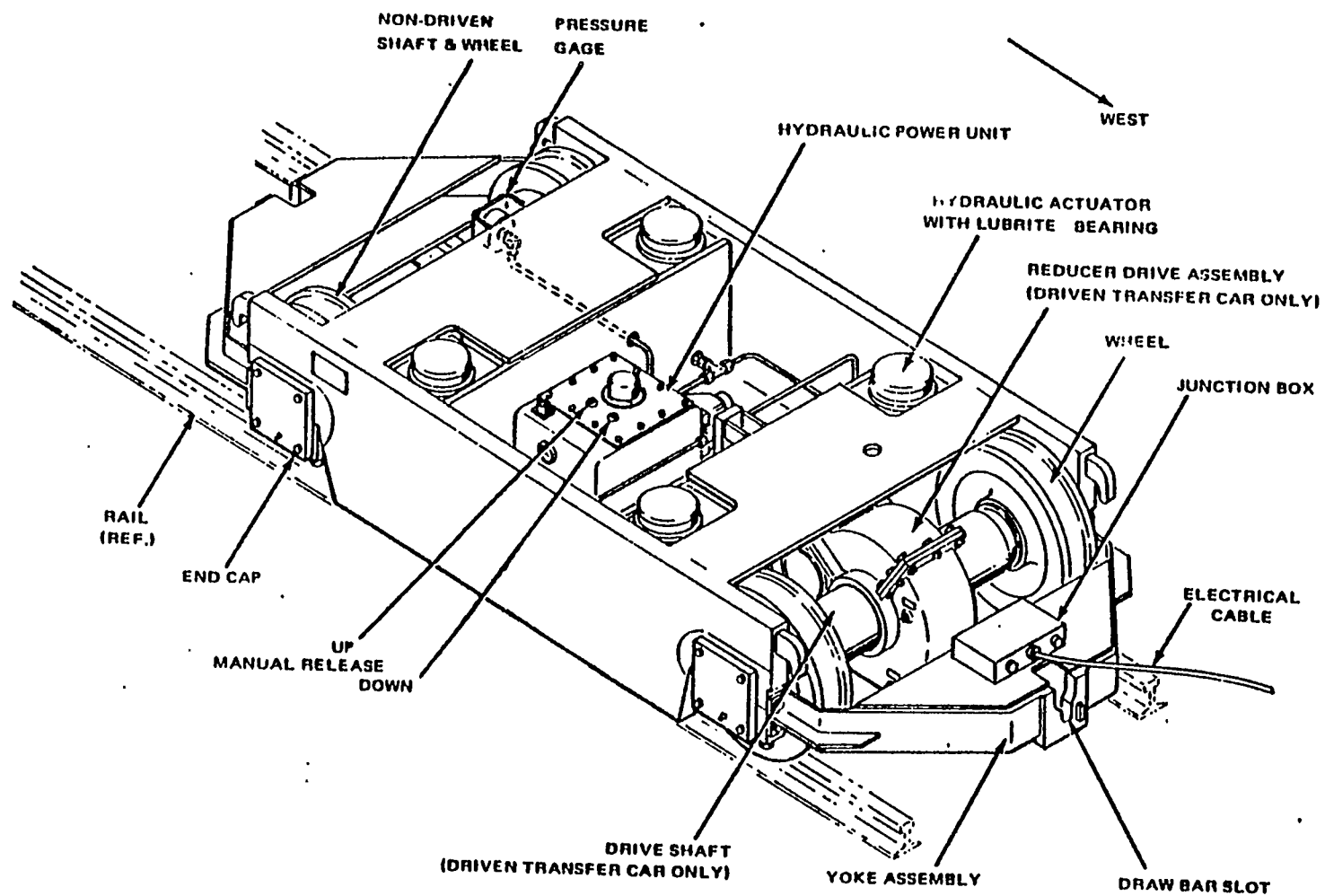


Figure 6-25 Transfer Car

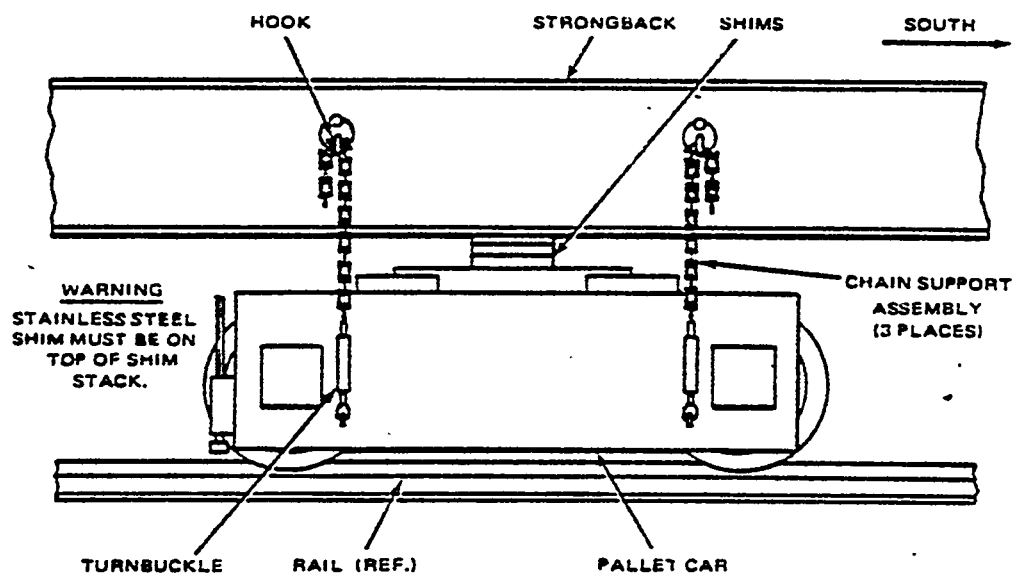
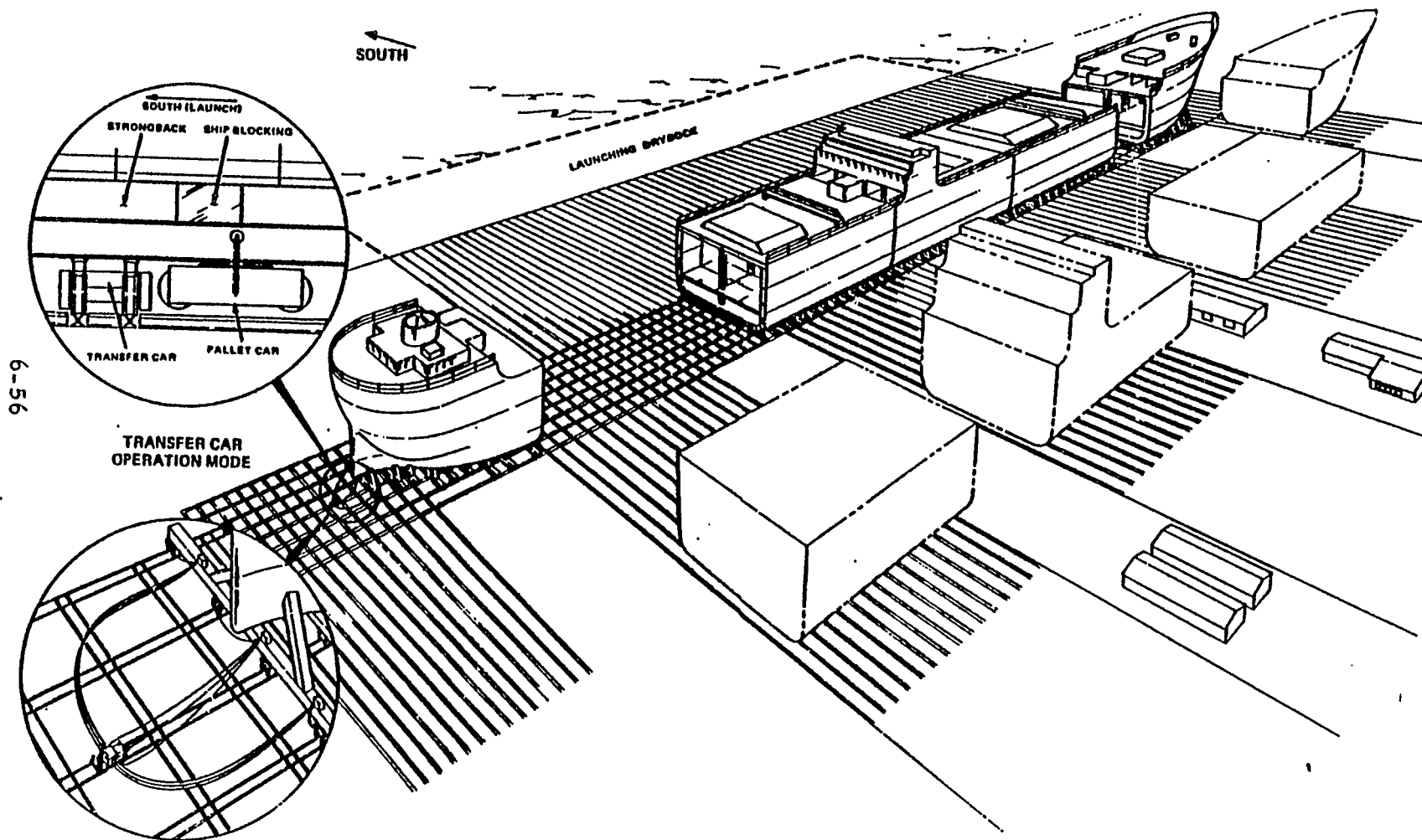


Figure 6-26. Pallet Car to Strongback Fastening



**Figure 6-27. Ship Assembly Area Showing Trackage Layout**

a. Component Description

**Main Power Unit** - The main power unit is a self-contained four-wheeled cart capable of powering 53 pallet cars or transfer cars plus appropriate strongbacks and ship module, or 105 transfer car hydraulic motors. Two power units are provided with the ship transfer system illustrated herein.

**Pallet Car** - The pallet cars are four-wheeled units which travel on rails. Each pallet car consists basically of wheels, axles, a strongback guide plate, bearings and seal assemblies, wheel thrust plate and end caps and all necessary hardware and electrical wiring. The ship transfer system illustrated in figure 6.27 requires over four hundred pallet cars, half of them driven and half non-driven.

**Transfer Car** - The transfer cars are four-wheeled units which travel on rails. Each transfer car consists basically of wheels, axles, bearing and seal assemblies, wheel thrust plates and end caps, four hydraulic actuators, a pressure gage calibrated in long tons, yoke assemblies, and all necessary hardware, electrical wiring and hydraulic equipment (see figure 6-25). Each hydraulic actuator incorporates a lubrite bearing for contact with strongbacks. Fifty-four transfer cars are required in the ship transfer system shown, half powered and the other half non-powered.

**Strongbacks** - The strongbacks are fabricated steel girders and are provided to transfer loading from the ship module's blocking to the pallet or transfer cars. In the ship transfer system shown are 52 three-car type strongbacks, and 60 five-car type strongbacks. The strongbacks incorporate

lubrite bearings which ride on stainless shims on each pallet car. The strongbacks are also equipped with the necessary electronic hardware for connecting power to the pallet cars.

Rail System - The rail system consists of rails and fabricated steel structures which provide areas of travel for the pallet and transfer cars. The rail system includes rail crossing assemblies and crane rail crossings. There are 760 rail crossings and 300 crane rail crossings provided in the installation shown.

#### System Applications

The ship transfer system is capable of lateral moving of an entire ship or any part of a ship in the areas served by the rail system.

#### **6.4.4 SUMMARY**

The series production of tankers will require numerous moves of short distances, over a reasonably level surface of assemblies and ship sections weighing hundreds of tons.

The results of the study indicate that if lifting (or lowering) to any extent, such as in the erection process, is not required. and lateral transport over a fairly level surface is the criteria, the heavy load moving systems are more effective and versatile than cranes of a comparable capacity. It will be recalled that units of the move systems can be used in many instances as a building platform from start of assembly to launch. In addition, comparisons of acquisition

and maintenance costs will in many instances favor the heavy load moving system over cranes of similar capacity. For budgetary cost estimates, the cost per ton of lift-move capacity for the heavy load moving systems presented herein range from \$50 to \$150 per ton of capacity, while cranes in 200 to 800 ton capacity cost from \$12,000 to \$20,000 per ton of capacity.

#### 6. 4. 5 RECOMMENDATIONS

- a. Where there is a requirement for lifting capability beyond the capacity that currently exists in a specific shipyard, heavy load moving systems should be given consideration.
- b. Shipyards should increasingly endeavor to utilize major load moving systems developed for other industries where practical and cost effective applications can be made.
- c. An evaluation should be made of the existing heavy lift capabilities and the increased revenue which would be generated (if any) by a significant increase in lift and/or move capacity (see section 6.1 of this portion of the study).
- d. Additional lift/move requirements generated by series production of ships should be analyzed to make full use of the engineering services provided by manufacturers of this type of equipment.

**VOLUME I I I**  
**PART 7**  
**JIGS AND FIXTURES**

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VOLUME III  
PART 7  
**JIGS AND FIXTURES**

**7.1 INTRODUCTION**

The Series Reduction of ships presents a shipyard the opportunity to take full advantage of the mass production experience and techniques, developed and proven by non-marine heavy industry. This part of the study addresses the feasibility of applying these methods *to* the shipbuilding process.

**7.2 NON-MARINE INDUSTRY OBSERVATIONS**

In order to observe and review the various production methods , currently in use, visits were made *to* companies that provide non-marine heavy equipment. The companies visited and the products are:

The Boeing Company - Large Commercial Aircraft  
Westinghouse Air and Brake (WABCO) - Off-the Road Trucks  
General Electric - Railroad Locomotives

A practice that was observed to be in use without exception; in all facilities visited, was the extensive use of and application of jigs and fixtures to the assembly process. Management personnel in the planning and operational departments of the companies visited were questioned concerning the merits of this practice, and the consensus of opinion on the subject was as follows:

- a) Najor importance is placed upon the use of tooling  
such as jigs and fixtures in the non-marine industry.

- b) Jig and fixtures are considered vital and necessary in order to perform the repetitive assembly operations, associated with high (series) production.

Based upon the widespread industrial use and the importance attached to jig and fixture usage, their application to series production of ships, is addressed in the following portion of this report.

After the jig and fixture applications currently in use by non-marine industry were thoroughly reviewed, the design and development aspects were investigated and compared with practices common to shipbuilding.

The use of jigs and fixtures was applied to the production process of the subject 150,000 DWT tanker, and the resultant effects were analyzed and compared with conventional ship production.

Note: In Volume III, Part 4, of this study, the application of of jigs and fixtures to the fabrication shop was developed in detail, forming a part of the over-all jigs and fixtures study.

While reviewing the use of jigs and fixtures, additional items were identified as having possible supplemental benefits to the major subject (jigs and fixtures) and are discussed briefly before presenting the full report. These items are:

1. Establishment of "dollar lines".
2. Expansion of jigs and fixtures to suit an expanded, or revised product line.
3. Massive or "Goliath" welding positioners.
4. Establishment of work stations, based on jig and fixture requirements.

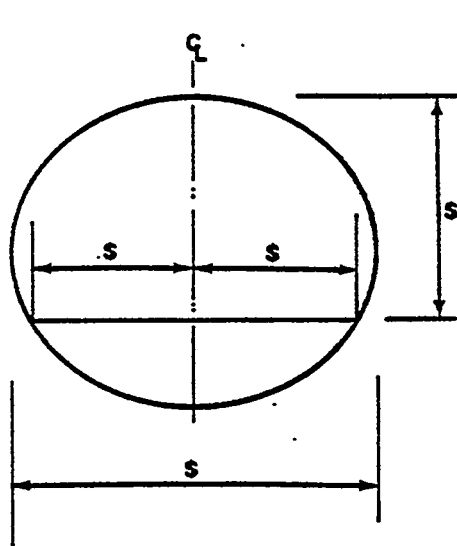
### 7.2.1 Dollar times for Dimension Control

In the aircraft industry, the tooling design effort is often started concurrently with the design of the aircraft to be produced. This early start is required in order to have the proper jigs and fixtures designed, built and set in place, in time to support the production schedule.

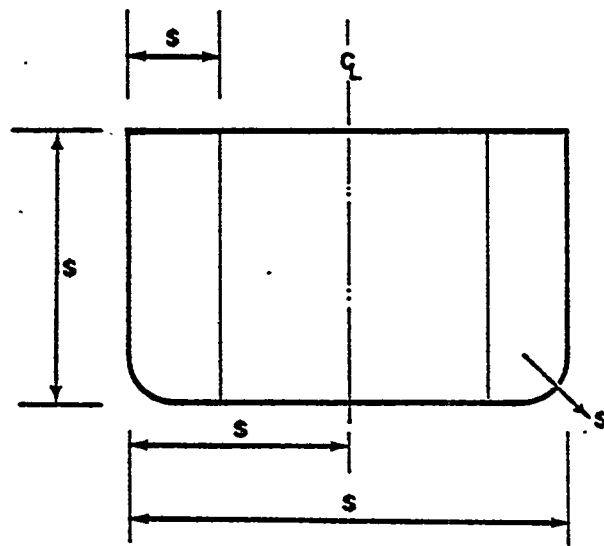
In designing the fixtures, the tool designer works together with the airframe designer as required to establish certain physical characteristics of the aircraft which will not be altered during the design development. In most cases, these "dollar lines" are defined as a surface or plane with some type of controlling dimension which allows the tooling designer to start the design of a fixture before the product has been completely defined.

In adapting this technique to shipbuilding (see figure 7-1), it seems reasonable to assume that certain key dimensions of the ship and its associated parts and equipment could also be established or "frozen" at an earlier phase of the design stage than is normally accomplished, thereby allowing a longer reaction time for further engineering design affected by space or arrangement considerations as well as the development of the jigs and fixtures.

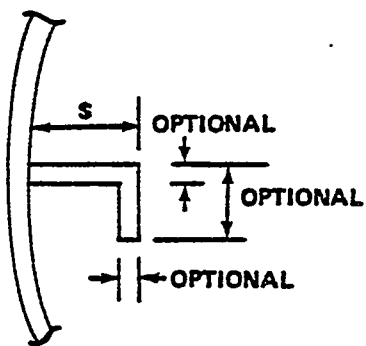
This technique could be applied to any of the shipbuilding disciplines, although the hull and machinery areas appear to be the most attractive for extensive application. While the technique is essentially an "engineering tool", its use could have an advantageous effect on the planning effort required to support production, when applied to a specific area during the design process.



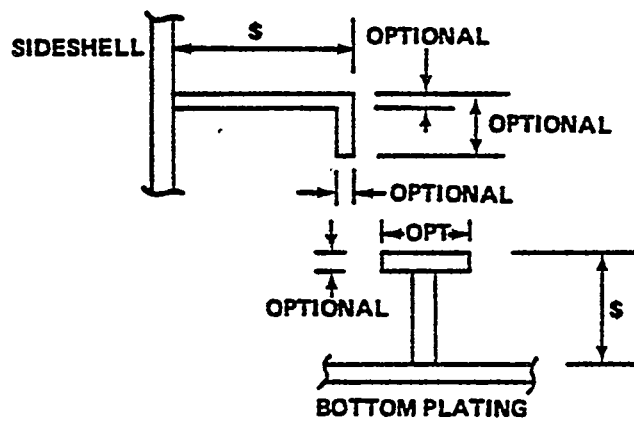
AIRCRAFT



SHIPBUILDING



AIRCRAFT



SHIPBUILDING

Figure 7-1 Dollar Line Applications for Aircraft and Shipbuilding

### 7.2.2 Design for Product Growth

In many non-marine industries, past experience has proven that while current designs must be developed to suit immediate requirements and to be competitive in the current marketplace, the trend for growth or expansion of the product is constant and should be recognized in the development of the initial design.

In the aircraft industry the introductory model of a given aircraft often incorporates a wing-frame section which has already been designed to adequately support the increased loadings produced by an increase in engine size or an expansion of the fuselage as required to expand the cargo area.

In the heavy equipment industries structural frames are initially designed to suit future expansion, as would be required by an increase in capacity or engine size.

In regard to jigs and fixtures, the planned growth pattern must be established as part of the initial design. The tooling is then developed so as to be expandable or adjustable as required to suit the characteristics of the "ultimate" product line.

Application of this technique is relevant to shipbuilding since the requirement to adjust or modify a ship or ship design, after initial construction? frequently occurs.

In terms of new design development if a shipyard were able to develop a satisfactory "family" of ships, each with common dimensions, jigs and fixtures could then be developed to suit the dimensions affected by the alternate size ships (see "Constant Principal Dimensions, Volume II, Part 2) and the usage or "life" of the fixture would be extended considerably.

In a similar manner, if a shipyard were successful in acquiring follow-on contracts to modify ships with the characteristics which were similar to those previously constructed, a majority of the jigs and fixtures which were already developed could be utilized in support of the follow-on contract. This would result in the realization of a significant savings in tooling costs. In some cases, existing hull assembly fixtures can be adapted by simply burning away a portion of the existing fixture as required to fit the contour of the follow-on ship.

#### 7.2.3 Use of "Goliath" Welding Positioners

In the heavy equipment manufacturing industry, welding positioners have been developed to assist in the production of welded structures weighing in excess of 200 tons.

These goliath positioners either rotate the entire structure as required to accomplish all welding in the "down-hand" position or regulate the height and attitude of the structure in order to sequentially adjust the structure to a convenient ground-level working height and position. (see figure 7-2)

In exploring applications to shipbuilding, any large welded structure such as a main engine foundation would make a suitable candidate for a similar application of a welding positioner. The candidate chosen should require a large amount of welding which cannot be accomplished automatically, in order to justify the development of the fixture. -

On a larger scale, similar applications have been made in shipbuilding as required to rotate an entire ship module. For example, at the Litton Erie yard, a 90 degree structural framework is built into the assembly shop floor, where modules are moved onto the fixture, rotated 90 degrees to suit the welding techniques employed and then

moved off the fixture (see figure 7-2). There are several similar systems in use in foreign shipyards, all of which essentially accomplish the same re-positioning of large structures to suit the respective welding techniques.

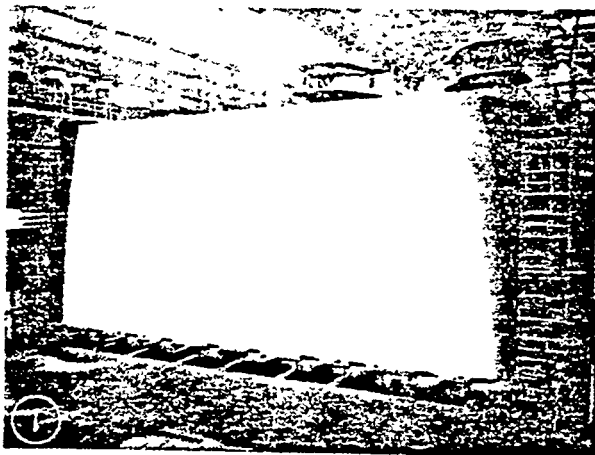
Specialized applications of extensive jig and fixture systems such as these can only be justified in anticipation of repeated use, as would be the case in series production of ships.

#### 7.2.4 Establishment of Work Stations Based on Application of Jigs and Fixtures

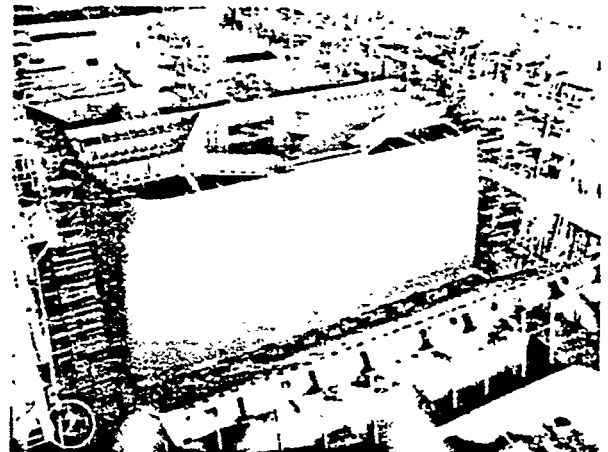
In shipbuilding, the use of jigs and fixtures is a secondary consideration which is only developed after the basic production planning effort is completed.

However, in many non-marine industries, the importance of jigs and fixtures is so great that the structural designers give full consideration to discrete assembly points so that the use of jigs and fixtures can be optimized. Once the assembly break point has been established and the assembly jig identified, the planning effort is then developed to suit the intended use of jigs and fixtures. By this process, the product is analyzed in details and characteristics, such as critical dimensional tolerances, are identified in support of the tooling design effort which follows. After establishing the method of fabrication, utilizing jigs and fixtures, the total production planning effort is accomplished to suit the manufacturing concept.

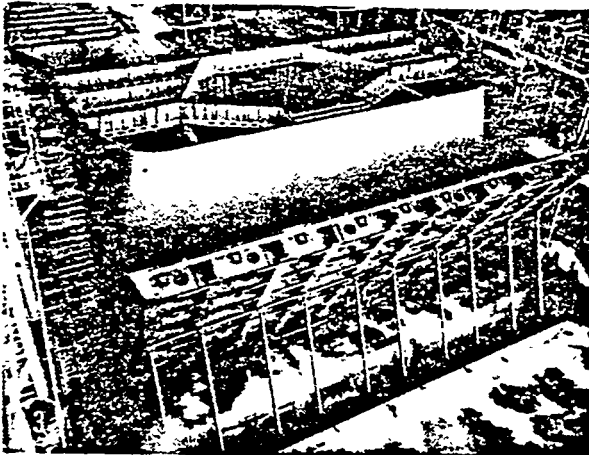
This procedure is not recommended for direct application in shipbuilding, since the jig and fixtures development phase in shipbuilding should be accomplished as part of the total planning effort. (See Production Planning, Volume III, Part 4).



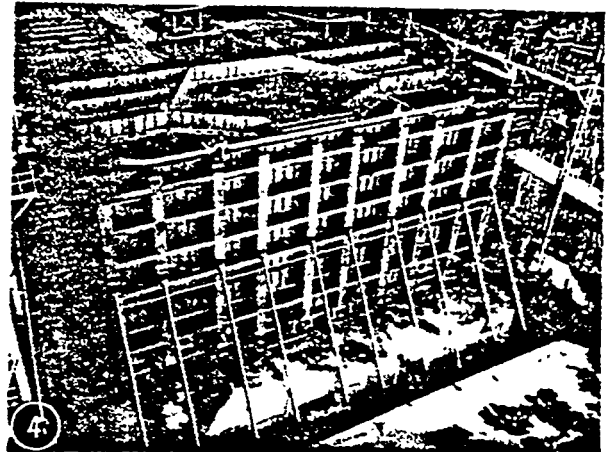
MODULE READY FOR ROTATION



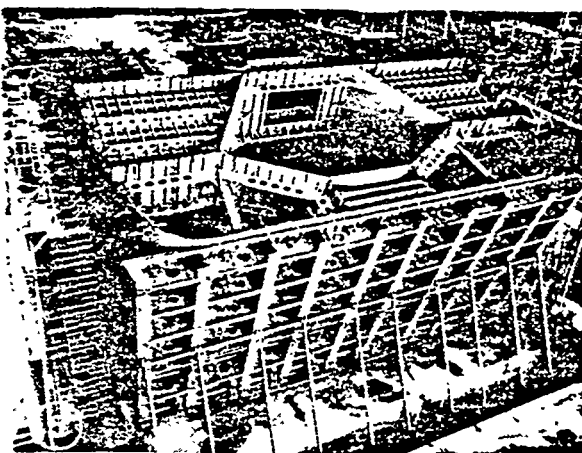
LAUNCH PLATEN RISES TOWARD MODULE



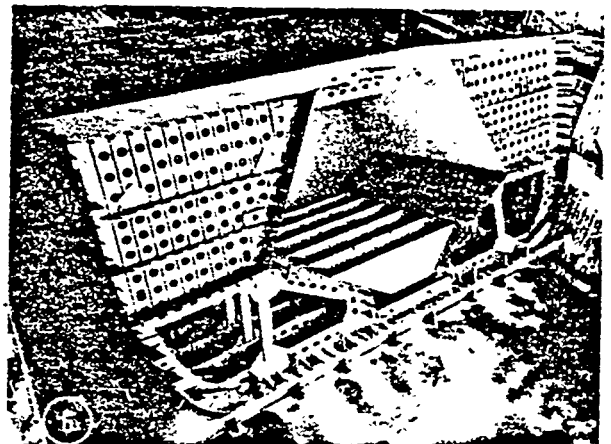
LAUNCH PLATEN NEARS MODULE



LAUNCH PLATEN IS SECURED TO MODULE



MODULE IN ROTATION TO GRAVING DOCK FLOOR



MODULE NEARS GRAVING DOCK FLOOR

Figure 7-2 700 Ton Module Being Rotated 90 Degrees At Ship Assembly Facility

### 7.3 JIG AND FIXTURE PLANNING

In the production planning effort as normally accomplished for single-ship productions jigs and fixtures are developed on a limited basis as part of the initial planning effort (See figure 7-3).

In many shipyards, the subject of jigs and fixtures is not recognized as a formal entity of the production planning effort and the production areas are left to pursue the subject independently on a strictly optional basis.

There are a number of disadvantages associated with this approach, which include:

- a. Design and construction of jigs and fixtures impacts the production workload schedule when accomplished by production personnel on a non-controlled basis.
- b. These efforts are usually accomplished utilizing scrap or surplus material, which is commendable, but not always effective.
- c. The costs of designing and fabricating the jigs and fixtures become "buried" in the total production effort, and no appreciation for either the cost of implementation or the associated manhour savings is ever developed.
- d. The system is totally dependent on the initiative, skill and resources available in production at the time of the need for special tooling, such as jigs and fixtures.
- e. By delaying the identification of special tooling needs to the last possible step in the production cycle, timeliness and lack of available material often cancel the opportunity to implement the necessary jigs and fixtures.

- f. Where jigs and fixtures are successfully implemented by the crafts, budgets and planned costs are rarely corrected to reflect the actual work content and methods being utilized. As a result, there is no net cost savings to the shipyard, although the productivity requirement was reduced in a specific area of production.

In series production shipbuilding, it is recommended that the development of special tooling requirements be accomplished as a part of the initial production planning effort, as shown in figure 7-4.

Using this approach, special tooling requirements are developed as a part of the over-all manufacturing plan and are coordinated with the various stationization plans developed during this period.

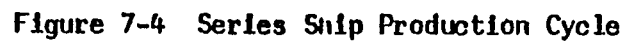
Accomplishment of this task is a part of the expanded production planning effort recommended for series production, which may require additional lead time prior to the actual start of production. Accomplishing this effort earlier provides for the following outlined advantages:

- a. By considering the jig and fixture applications earlier, the opportunity for revising the ship design to improve producibility is increased.
- b. Early development of special tooling will allow sufficient time for fabrication and obtaining the needed materials including the utilization of surplus material.
- c. Where the fixtures are built in the shipyard, earlier design allows their construction to be accomplished on a time available basis, with minimum disruption to production work schedules.

7-11



**7-12**



- d. Where the fixtures are designed by a support group, such as manufacturing engineering, valuable production work force time is not channeled away from its primary objective.

There are a number of related consideration included in other parts of this report which affect the planning aspect of jigs and fixtures. These are as follows:

- a. The use of jigs and fixtures is often instrumental in the establishment of work stations. Volume III, Part 3, of this study should be reviewed for further development of this area.
- b. The development and planning for jigs and fixtures is very closely associated with the preparation of both the Stationization Plan and the Manufacturing Plan which are covered in volume II, Part 1, of this-study.
- c. The opportunity for early identification of tooling needs is very closely associated with the characteristics of the shipyards production planning system employed. (Volume III, Part 2).

#### 7.4 TYPICAL APPLICATION OF JIGS AND FIXTURES

For demonstration purposes, the 01 assembly of configuration O-A was selected as a candidate for a comparison study which would evaluate the advantages, if any, of utilizing jigs and fixtures during the final assenbly of the unit.

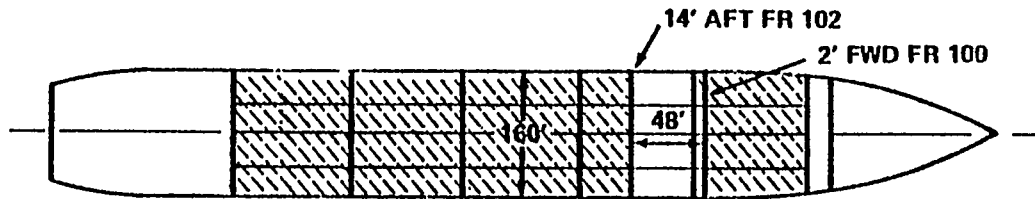
This unit is an inboard innerbottom assembly (01) of the tanker midbody configuration D-A as shown in figure 7-5. The total weight is 144 tons. The longitudinal girders and transverse floors form a typical "egg crate," with the bottom shell beneath and the tank top plating forming the overhead of the assembly.

The concept for assembly of this unit is shown in figure 7-6. The separate floors and girders are fabricated on a specialized assembly line in the fabrication shop (See Production Areas and Shops, Volume III, Part 2) and inserted into an egg crate jig which holds these plates in place while they are finally fitted and tack-welded. Temporary bracing is also added to hold the unit together while it is removed from the fixture and set on its "side," at an alternate final welding position. The unit is welded entirely downhand, first on one side of each structural intersection and then on the other, by rotation of the unit at this location.

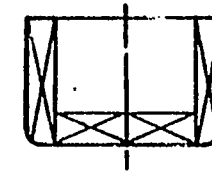
The tank-top assembly manufactured in the large panel line is placed in an inverted position to receive the welded egg crate. After proper alignment, regulation, etc., the egg crate is welded in the downhand position to the tank top.

At this point the unit is "pre-outfitted", as required to install pipe or other distributive system elements, and then turned 180 degrees and set down on the bottom shell sub-assembly in the ship-right position.

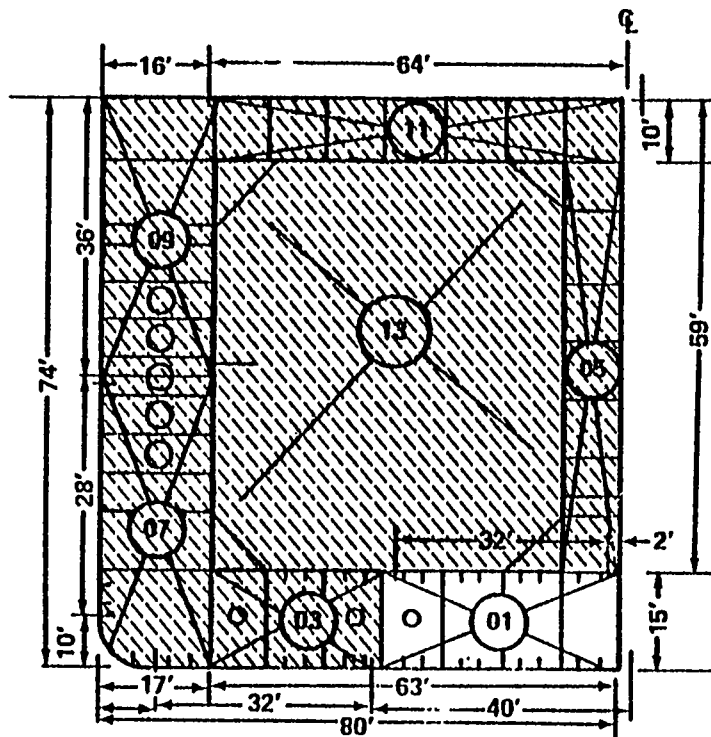
These units are welded together, again in the down hand position completing the sub-assembly sequence.



WT 2' - 0" FWD FR 100 TO 14' - 0" AFT FR 102  
 1639.4 S. TONS 48' SECTION W/TRANS BHD  
 1478.7 S. TONS 48' SECTION WO/TRANS BHD



7-15



ASSY	WT (S. TONS)
01-01 P	144.61
02 S	144.61
03 P	117.18
04 S	117.18
05 S	91.74
06 S	177.00
07 P	177.00
01-08 S	112.71
09 P	112.71
10 S	102.00
11 P	102.00
12 S	120.33
13 P	120.33

Figure 7-5 Tanker Configuration D-A

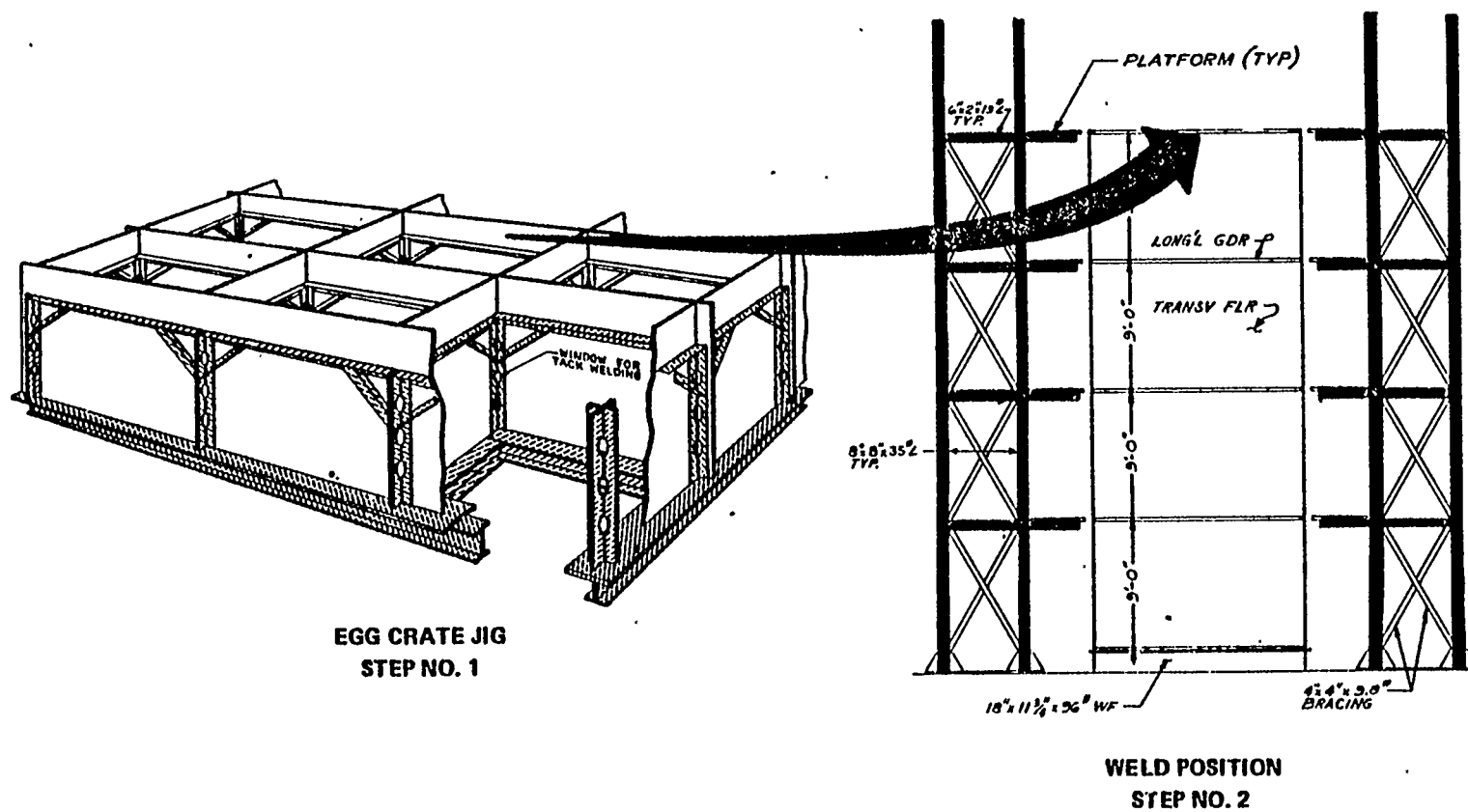


Figure 7-6 Subassembly Sequence

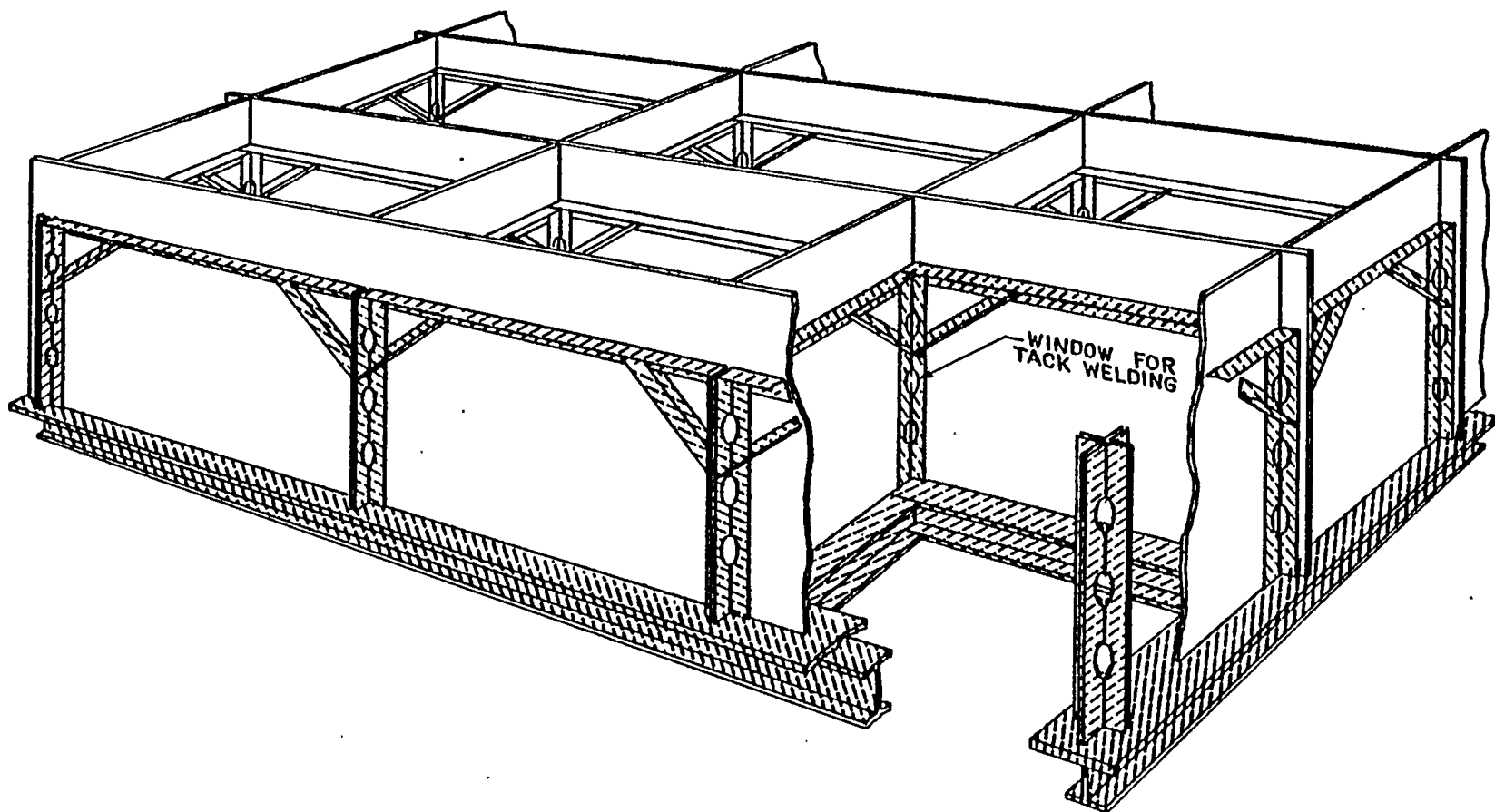
#### 7.4.1 Egg Crate Function (See Figure 7-6)

The egg crate fixture is a fabrication aid for shipfitters and is used in building the crate of the innerbottom assembly 01-OIP which is included in configuration D-A. The design of the fixture provides for a logical installation sequence of the longitudinal girders, transverse floors and other items such as partial tank bulkheads, etc.

The innerbottom structure of a ship is one of the most critical areas requiring dimensional control and alignment. The use of the egg crate fixture mechanically establishes the critical dimensions and locations of the various structural girders and floors thus minimizing the effects of human error associated with alignment. It also eliminates the requirement for initial layout, plumbing and leveling of follow-on innerbottom sub-assemblies.

The design of the fixture allows for adequate tack-welding of the pieces into an integral innerbottom structural sub-assembly and assures "as built" dimension corresponding to engineering design information.

7-18



#### 7.4.2 Egg Crate fig Cost

##### Direct Labor

Fit	108' of 1" plate to same @ .1829 manhours per foot	= 19.75 mhrs
Weld	216' of 1" plate to same @ .1304 manhours per foot	= 29.17 mhrs
Fit	720' of 21" x 13" x 142# WF to 1" plate @ .1366 mhrs per foot	= 98.35 mhrs
Weld	475' of 3/16" Int downhand @ .0956 manhours per foot	= 45.41 mhrs
Fit	236' of 6" x 6" x 1" to 1" PL @ .0732 manhours per foot	= 17.28 mhrs
Weld	236' of 3/16" Int downhand @ .0956 manhours per foot	= 22.56 mhrs
TOTAL MANHOURS = 231.52 x \$12.00 per hour		= \$2,778.24

##### Material

720 lin. ft. of 21" x 13" x 142# WF @ 15¢ per pound	= \$15,336.00
720 lin. ft. of 24" x 1" plate @ 15¢ per pound	= 8,813.00
3,312 lin. ft. of 6" x 6" x 1" angle @ 15¢ per pound	= 18,580.00
TOTAL MATERIAL COST	\$42,729.00
TOTAL DIRECT LABOR	2,778.24
TOTAL JIG COST	\$45,507.24

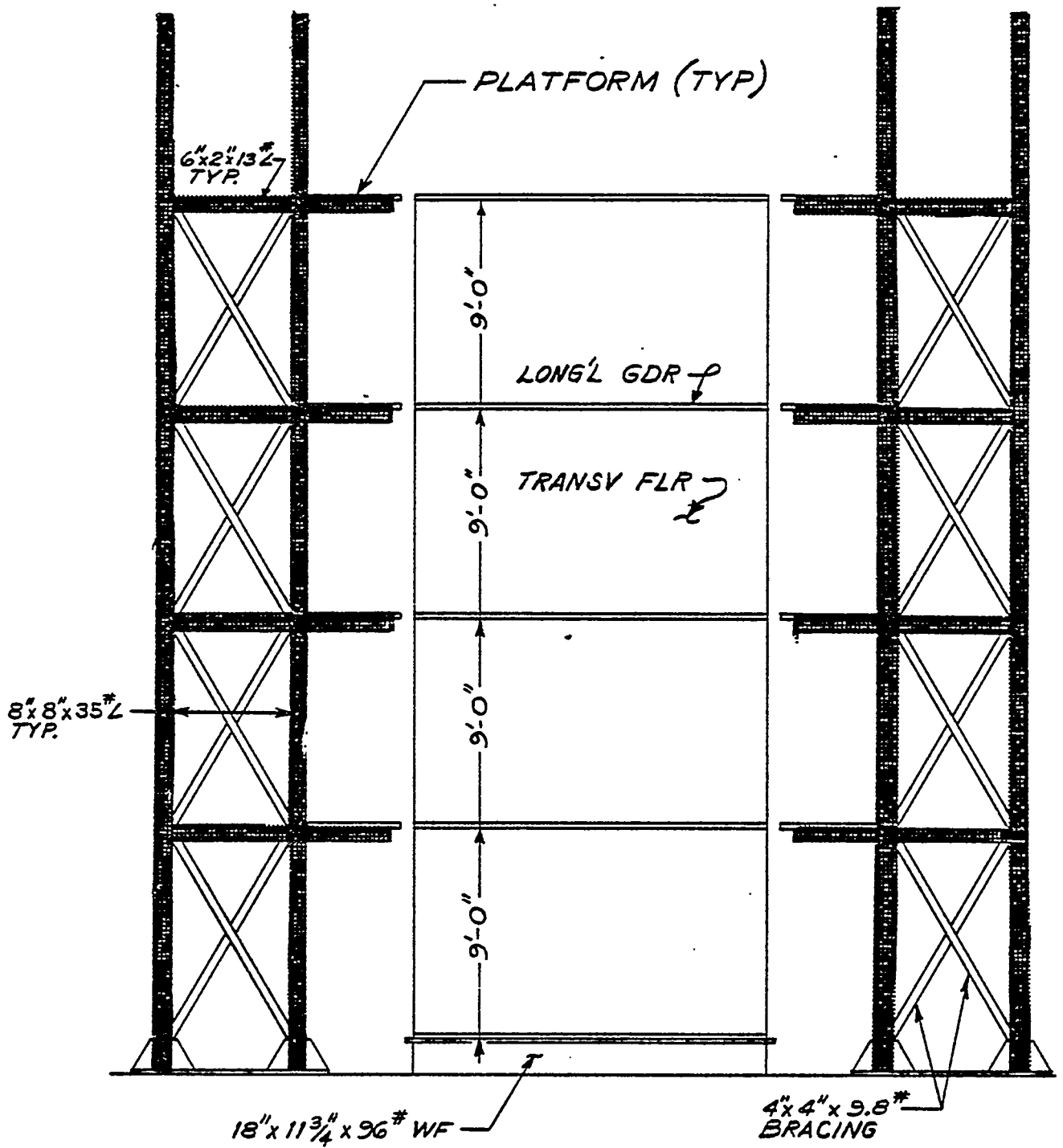


Figure 7-8 Weld Position Fixture

#### 7.4.3 Welding Fixture Function (See Figure 7-8)

The welding fixture as shown in Figure 7-8 is a specialized adaptation of scaffolding, with the addition of permanently installed utilities, available at 9' 0" levels, matching the height of the egg crate floors in the inverted position.

The use of this fixture is advantageous in that access to the assembly is improved, the required utilities are conveniently available, and the specialized requirements associated with the sub-arc welding as intended to be used are satisfied.

The fixture can be further developed to incorporate a removable cover which would provide weather protection where there is a requirement. Where high winds are of concern due to effects on welding, large canvas sheets can also be draped on the side of the structure to minimize disruption of the welding process.

For the purposes of this study, the total costs of fabricating the welding fixture have been included in the analysis. Where existing scaffolding of a suitable type is available, the cost of this fixture would be substantially reduced.

#### 7.4.4 Welding Fixture Cost Estimate

##### Direct Labor

Fit	6" x 2" x 13# channel to 8" x 8" x 35# WF (100 ft.) @ .6031 manhours per foot = 60.31 manhours
Weld	200' of 3/16" cont. downhand @ .1304 manhours per foot = 26.08 manhours
Fit	133' of 4" x 4" x 3/5" L to 5" x 5" x 35# WF @ .6151 manhours per foot = 81.81 manhours

Weld	133' of 3/16" cont. downhand @ .1304 manhours per foot = 17.34 manhours
Fit	27' of 8" x 8" x 35# WF to base @ .6031 manhours per foot = 16.28 manhours
Weld	54' of 3/16" cont. downhand @ .1304 manhours per foot = 7.04 mnhours
Fit	18" xx 11-3/4" x 96// WF to same (28') @ .6778 manhours per foot = 18.98 manhours
Weld	56' of 3/16" cont. vert. @ .1670 manhours per foot = 9.35 manhours

TOTAL MANHOURS = 235.59 x \$12.00 per hr. = \$2,827.08

#### Material

320 sq. ft. of 4' x 4' x 3/4" plate	= 9,792 pounds x 156 per lb. = \$ 2,469.00
900 Lin. Ft. of 8" x 35# WF	=31,500 pounds x 156 per lb. = 4,725.00
400 Lin. Ft. of 6" x 2" x 13#	= 5,200 pounds x 15(5 per lb. = 780.00
MOO tin. Ft. of 4" x 4" x 3/8" L	=17,640 pounds x 15c per lb. = 2,646.00
Scaffold Board (1800 sq. ft.)	600.00
Ladders (100 Lin. Ft.)	500.00

TOTAL MATERIAL COST	\$10 ,720.00
TOTAL DIRECT LABOR COST	2,827.08
TOTAL 31G COST	\$13,547.08

SPECIAL TOOLING COST  
SUMMARY

Weld Fixture

Labor	2,827.05
Material	10,720.00
Total	13,547.08

Egg Crate Fixture

Labor	2,778.24
Material	42,729.00
Total	45,507.24

special Tooling Costs	59,954.37
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#### 7.4.5 Single Ship Production Processes W/O Fixture

Assembly-01 - Inboard Innerbottom, Port  
40' x 48' x 15'

Fit Longitudinal girders and transverse floors to same and tank top.

.Fit 272' of floors and girders to tank top @ .7645 manhours per foot	207.94 manhours
.Fit 360' of floors and girders to same @ .7242 manhours per foot	260.71
Total fitting manhours	468.65

Weld

.Weld 544' of 5/16" continuous downhand @ .1304 manhours per foot	70.94
.Weld 720' of 5/16" continuous vertical @ .2409 manhours per foot	173.45
Total Welding Manhours	244.39

Fit Longitudinal girders, transverse floors and tank top  
sub-assembly to bottom shell.

.Fit 384' of floors and girders to bottom shell @ .7645 manhours per foot	293.57 manhours
Total fitting manhours	467.38

Weld

.Weld 768' of 5/16" continuous downhand @ .1304 manhours per foot	100.15
.Weld 480' of 5/16" continuous vertical @ .2409 manhours per foot	115.63
Total welding manhours	215.78

TOTAL MANHOURS ASSEMBLY-01 = 1,396.20 manhours

#### 7.4.6 Series Ship Production Process W/Fixtures

Assembly 01 - Inboard Innerbottom, Port

40' x 48' x 15'

Cum. Manhours 274.62

S/A-01-01 (No sub-assembly cost) Panel Shell

S/A-01-02

Fit and Welding in Egg Crate Jig	Manhours	63.93
----------------------------------	----------	-------

Bottom Shell - Integrate to S/A-01-01	Manhours	93.11
---------------------------------------	----------	-------

S/A-01-03

Tank Top - Integrate to S/A-01-01 & 01-02	Manhours	97.61
---	----------	-------

TOTAL MANHOURS 01 = 274.62

#### 7.4.7 Cost Comparison

The following represents total direct labor, material and equipment costs expressed in dollar values. These costs are comparatively itemized with respect to single ship production vs. series production. A value of \$12.00 per hour was assigned to direct labor manhours for the calculations of dollar values.

\*Total Direct Labor = 1,396.20  
1,396.20 x \$12.00 = \$16,754.00

Total Dollar Value = \$16,754.00

\*Total Direct Labor = 274.65  
274.65 x \$12.00 = 3,295.80

Total Special  
Tooling Cost = 59,054.32

Total Dollar Value \$62,350.12

As depicted in the above chart, the cost of single ship production through series production processes, substantially surpasses the cost of single ship production through conventional processes (without automated lines) by approximately 272 percent.

Example: \$62,350.12 = single ship production through series processes.

\$15,754.00 - single ship production (conventional processes).

However, the cost of single ship production (conventional) surpasses the cost of the second ship of the series by approximately 88 percent.

Example: \$16,754.00 = single ship production (conventional)

\$8,901.12 = series production less initial equipment cost

Based on the preceding cost analysis, the following cost comparison of single ship production vs. serie's ship production for ten shipsets of innerbottom assemblies is developed.

Table 7-1. Cost Comparison Conventional Vs. Series Production				
SHIP NO.	Per Ship	Cum	Per Ship	Cum.
1	\$ 16,754	\$16,754	\$62,350	\$62,350
2	15,414	32,168	3,032.	65,382
3	14,680	46,848	2,888	68,270
4	14,181	61,029	2,790	71,060
5	* 13,S06	74,935	2,716	73,776
6	13,506	88,341	2,657	76,433
7	13,253	101,599	2,608	79,041
8	13,047	114,646	2,566	91,607
9	12,862	127,508	2,530	84,137
10	12,702	140,210	2,499	86,636
TOTALS	\$140 ,210	\$140,210	\$86,363	\$86,636

#### 7.4.8 Conclusions:

As illustrated on the attached chart, a loss of approximately 272 percent due to special equipment and tooling cost is realized on the first ship within a series of ten ships. However, a total cost savings of approximately 400 percent is realized on ships 2 - 10 after the initial cost of special tooling and equipment have been absorbed.

\* The break even point for special tooling justification found of the fifth ship within a ten-ship series.

#### 7.5 JIG AND FIXTURE APPLICATION TO ASSEMBLIES WITH SHAPE

In the applications discussed so far, both in this section and in the Volume III, Part 2 section, the sub-assemblies used as subjects were essentially flat in nature, and particularly adaptable to the use of jigs and fixtures.

The benefits resulting from the use of jigs and fixtures are potentially greater, however, when applied to structural units with curved plate, where the fitting time is proportionately greater, as is the time required to establish ground blocking or other means of supporting the curved plate sub-assembly during the joining process.

As an alternate to "custom" making the ground blocking to suit the varying shape of alternate curved assemblies "universal" systems have been developed and used successfully with an appreciable reduction in the amount of time required for establishing the ground support.

Figures 7-9 through 7-11 show one example of an adjustable "pin" set-up, where a permanent installation of pins are used to support curved plates by adjusting the heights of the pins to the desired level.

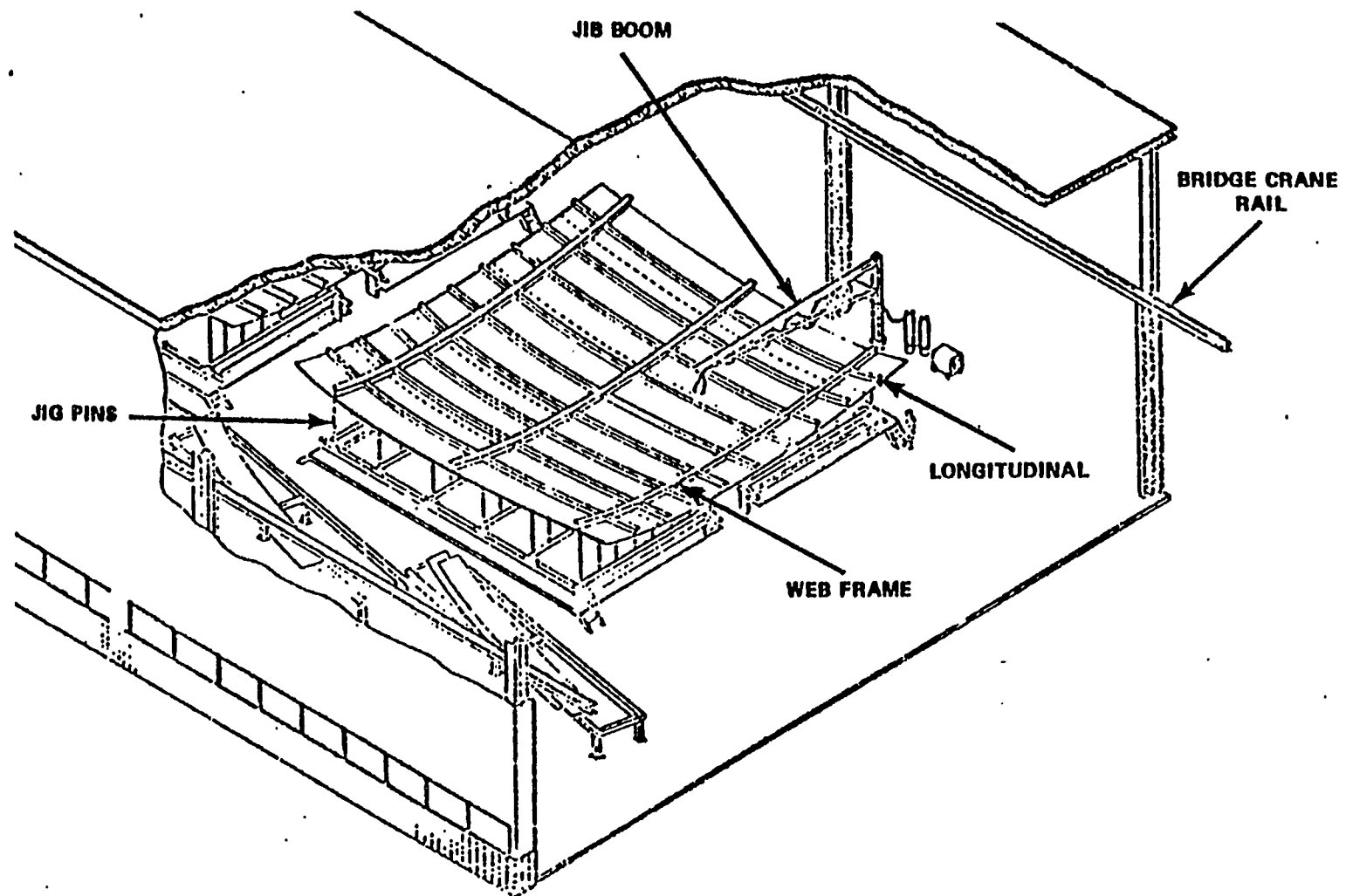


Figure 7-9. Curved Panel Shop

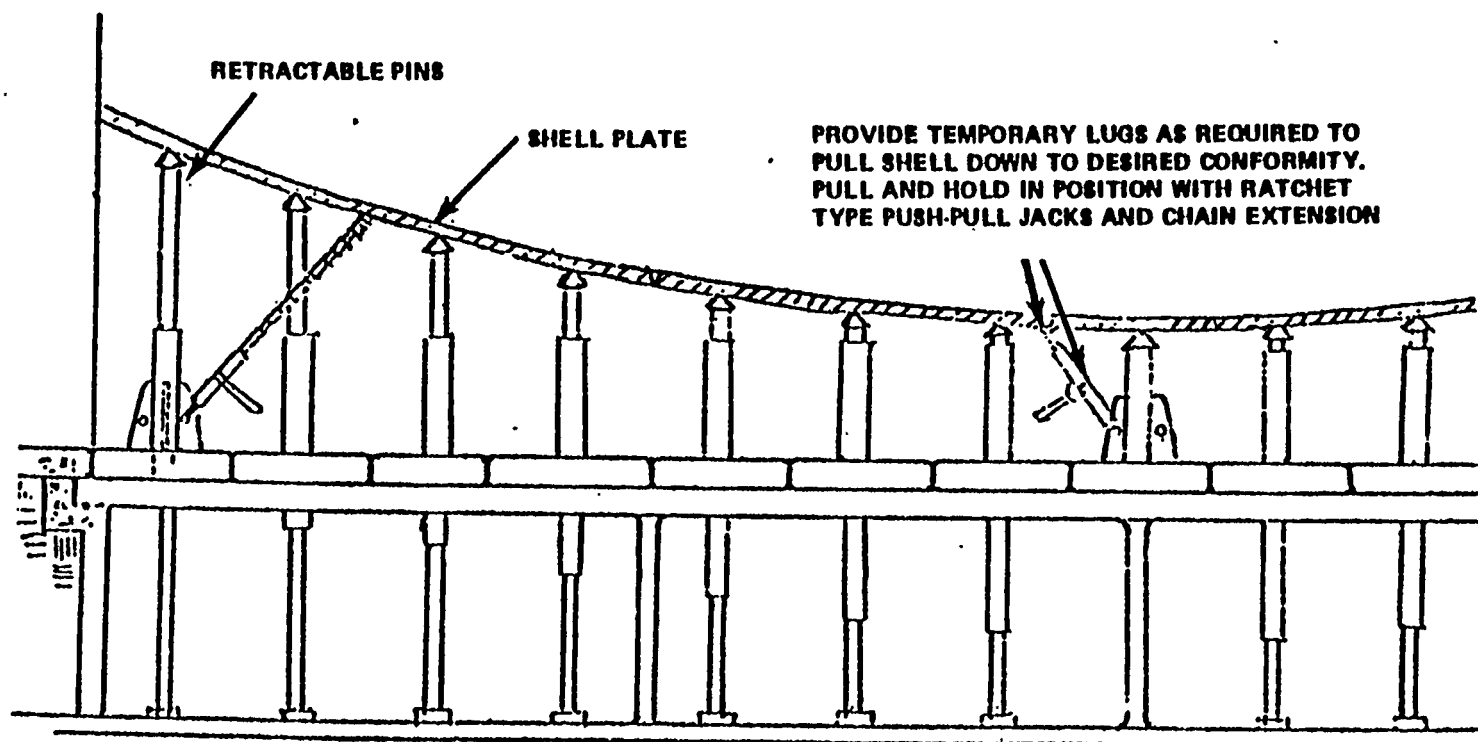


Figure 7-10. Cross Section of Adjustable Pins

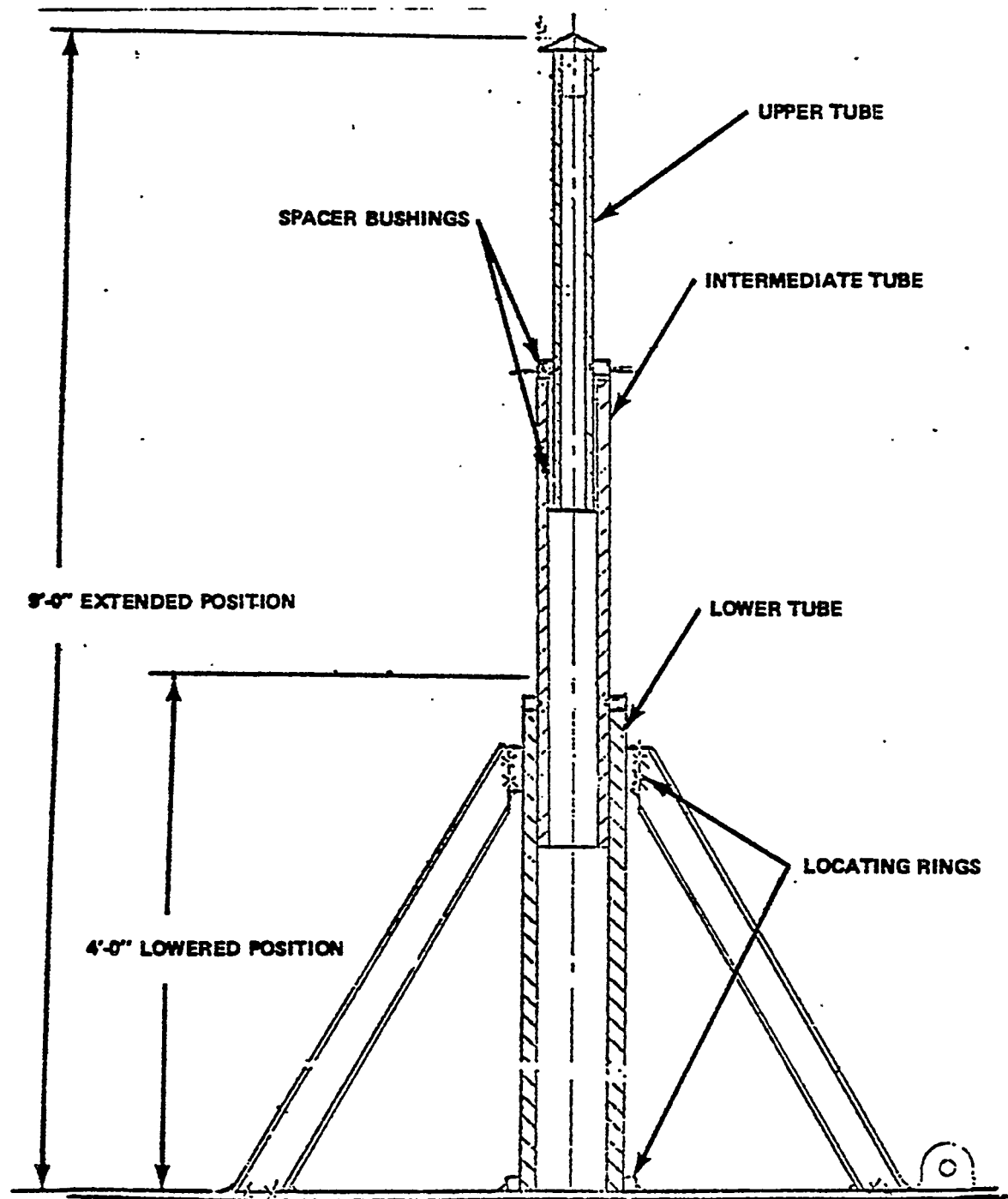


Figure 7-11. Shell Assembly Fixture

In an alternate approach, pipe "extensions" were made to slip over the anchored angles of a steel platen, as shown in figure 7-12. Here the pipe supports are not adjustable, but nevertheless were effective in reducing the required set-up time, since they were used for similar units in a repetitive mode.

## 7.6 SELECTED JIGS AND FIXTURES

In addition to the jigs and fixture designs normally developed for use in support of hull fabrication, there are a number of additional applications which are particularly suitable for support of series production. These are shown in figure 7-13 through 7-21.

These applications were reviewed and on a judgment basis the ones which could be effectively developed for series production were selected for inclusion in this section in an effort to show the wide range of variation in fixture requirements which is common to a single ship design.

In reviewing these applications, the time required to develop and construct these fixtures must be recognized. Future efforts to prepare for series type production must include proper time allowances to incorporate similar applications.

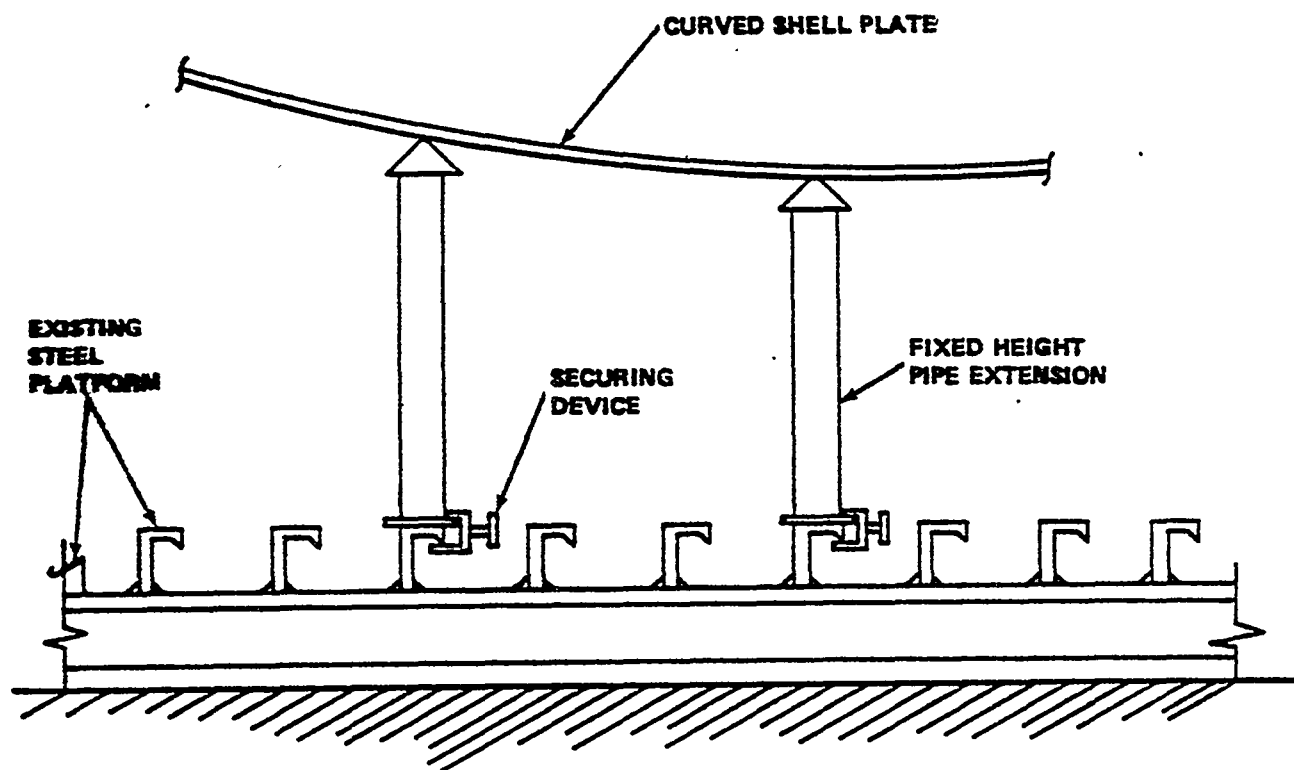


Figure 7-12. Adapting Existing Steel Platen to Curved Plate Assembly

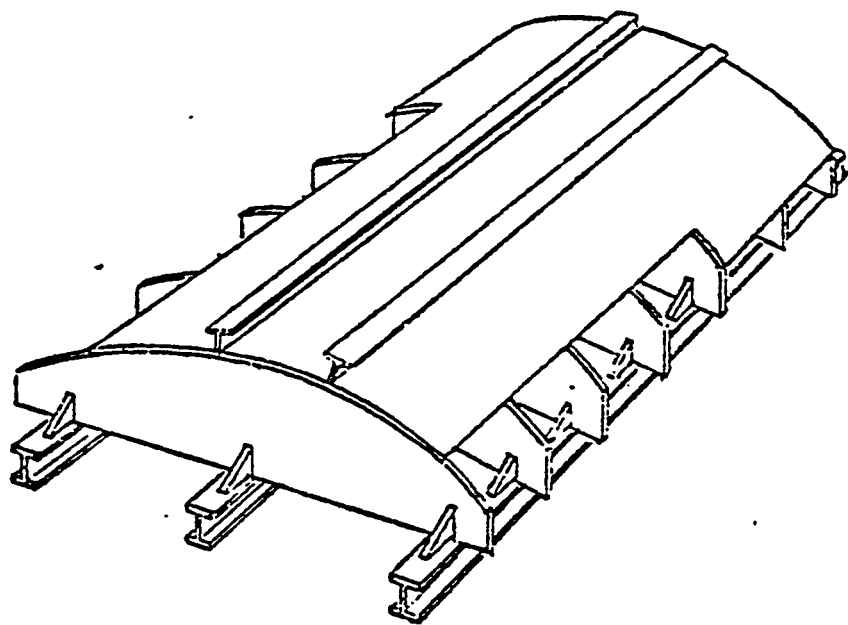
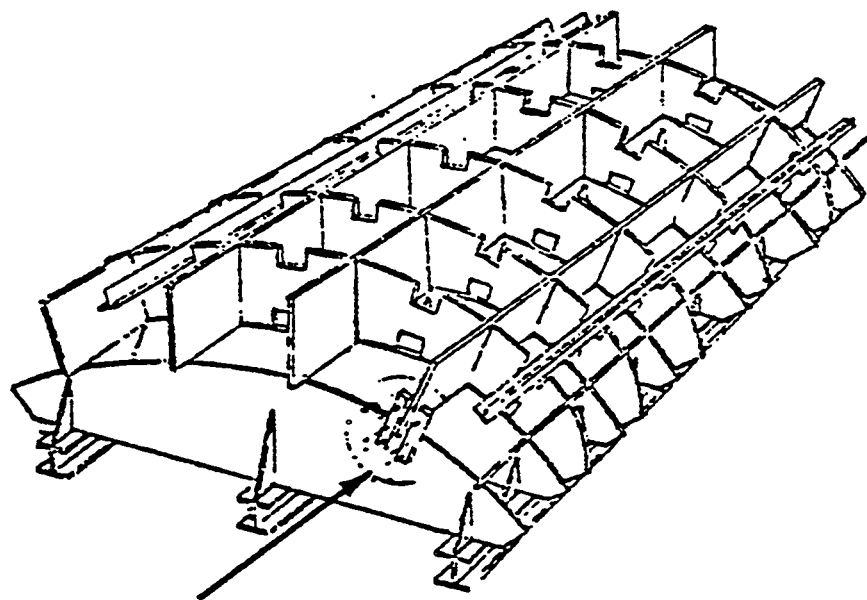
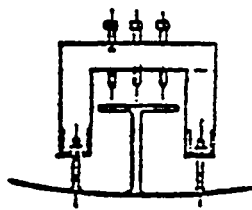


Figure 7-13. Weld Fixture for Innerbottom Tank Top

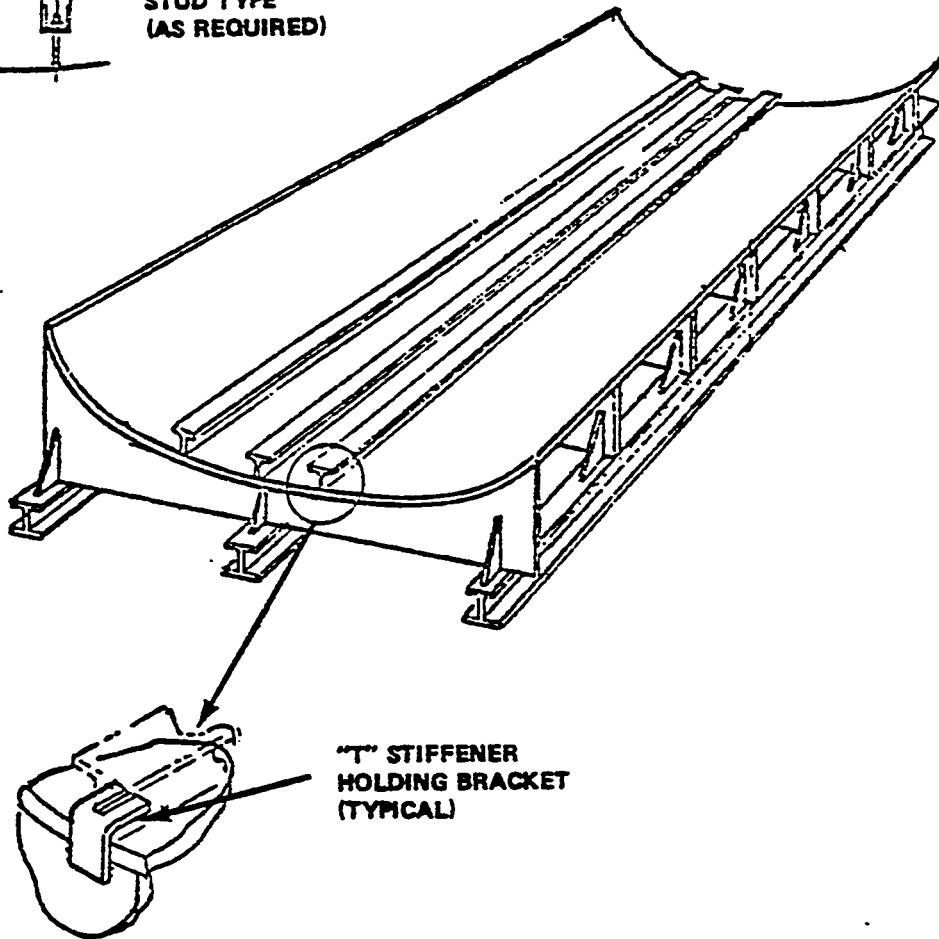


**STUD WELDED  
LOCATORS AND PUSHER  
TYP. EACH INTERSECTION**

Figure 7-14. Egg Crate Weld Fixture



**TYP. SHIPFITTER  
PULL TOOL  
STUD TYPE  
(AS REQUIRED)**



**"T" STIFFENER  
HOLDING BRACKET  
(TYPICAL)**

**Figure 7-15. Weld Fixture for Innerbottom Shell**

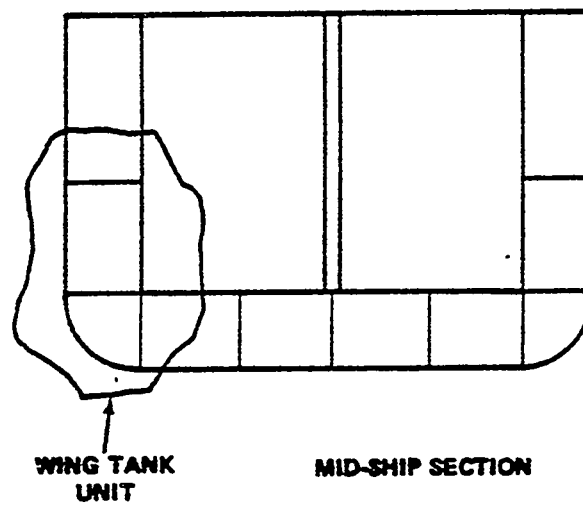
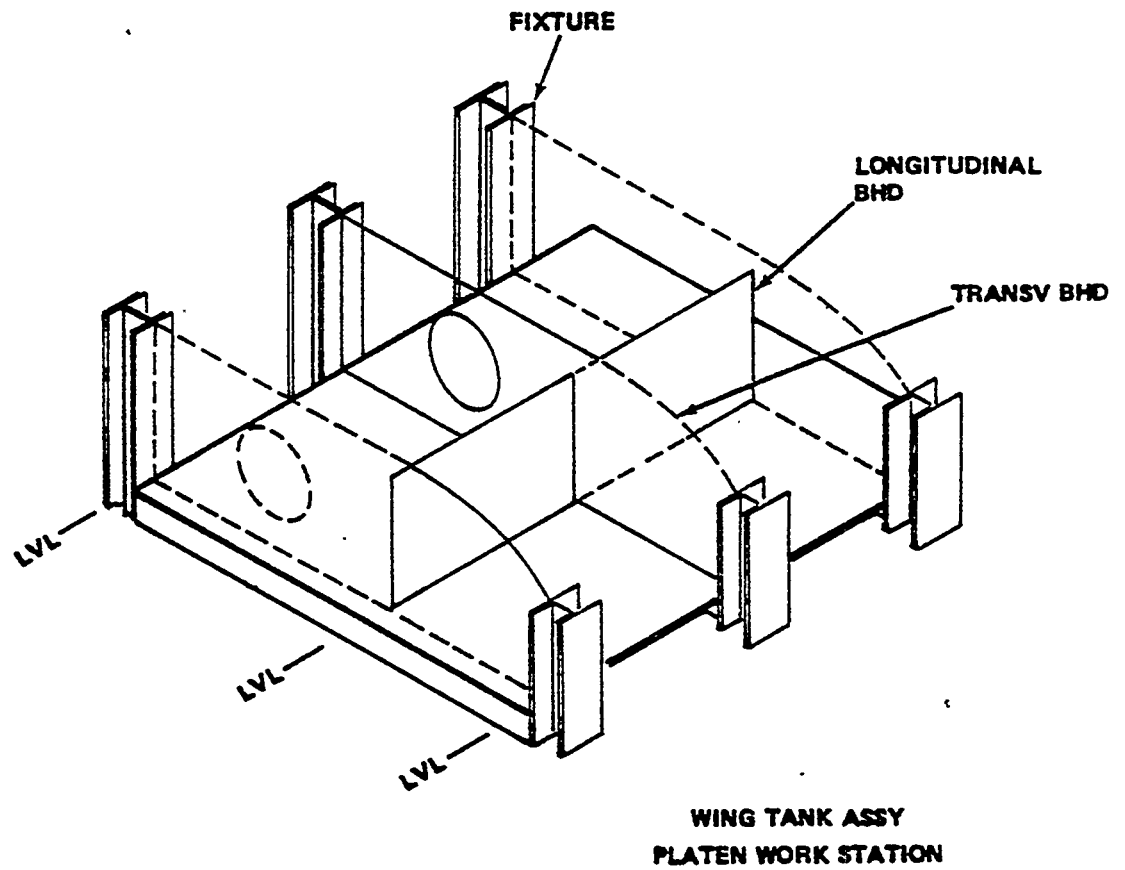


Figure 7-16, Wing Tank Assembly and Weld Fixture

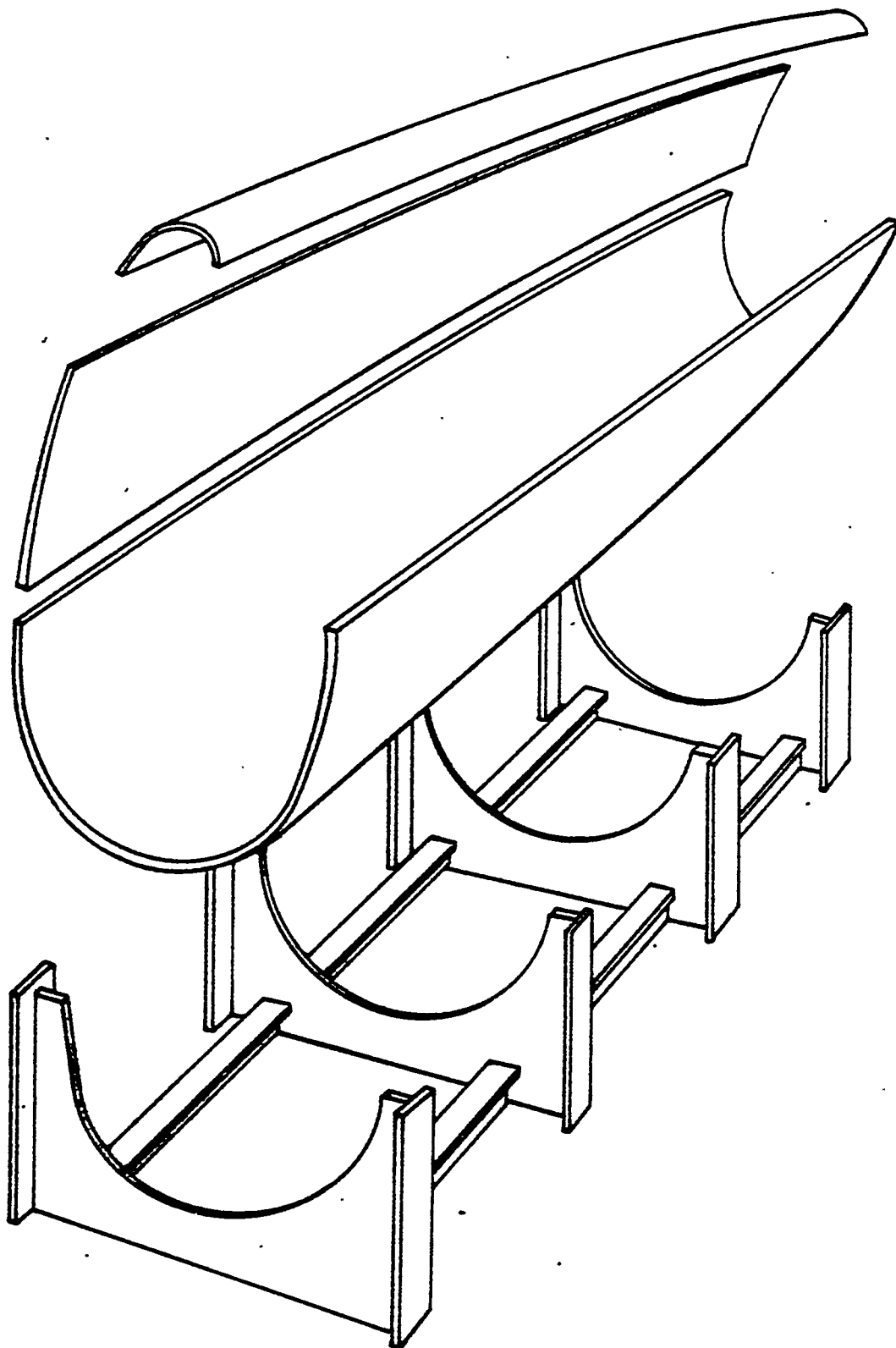


Figure 7-17. Stack Assembly and Weld Fixture

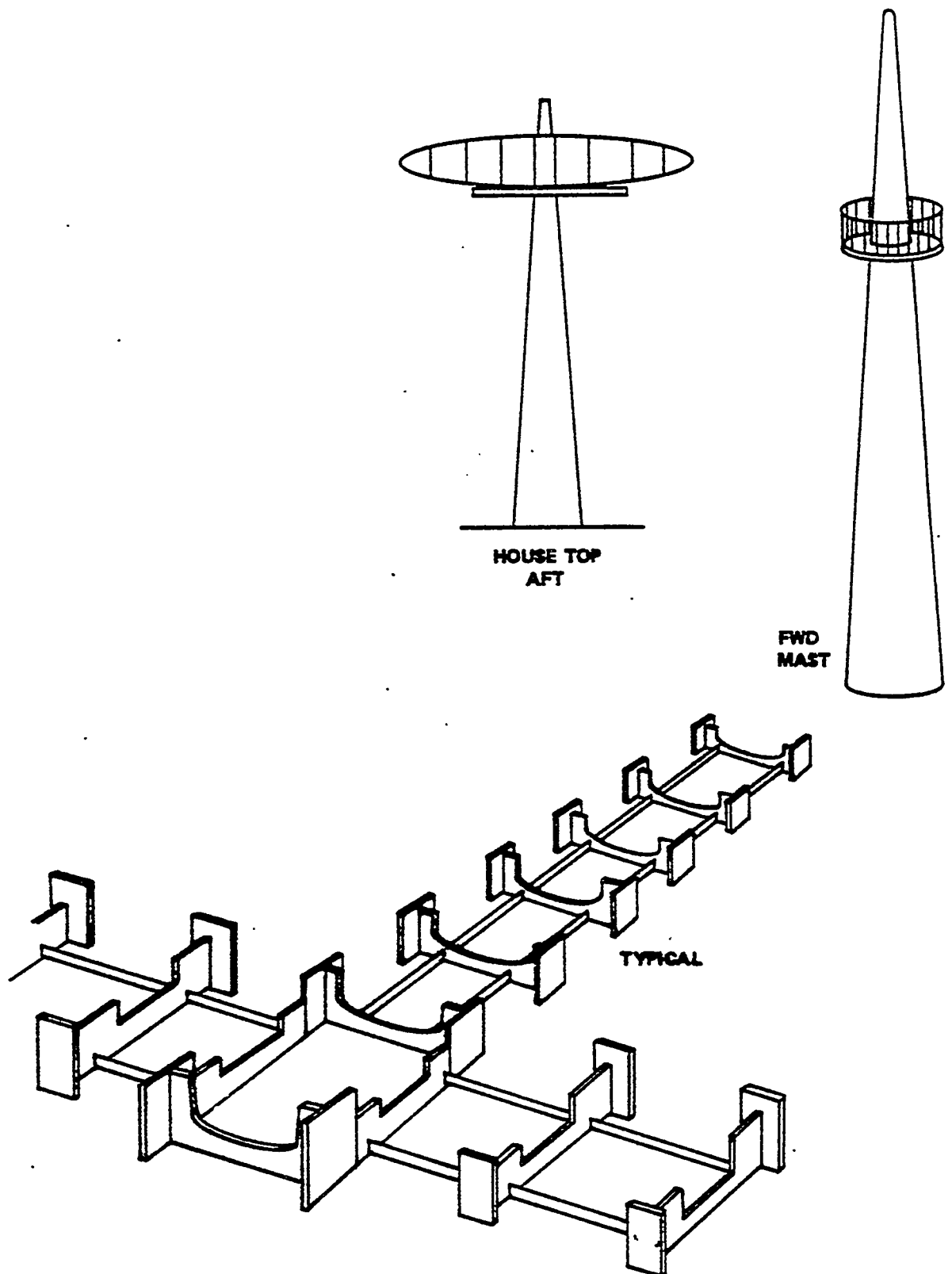


Figure 7-18. Mast Assembly and Weld Fixture

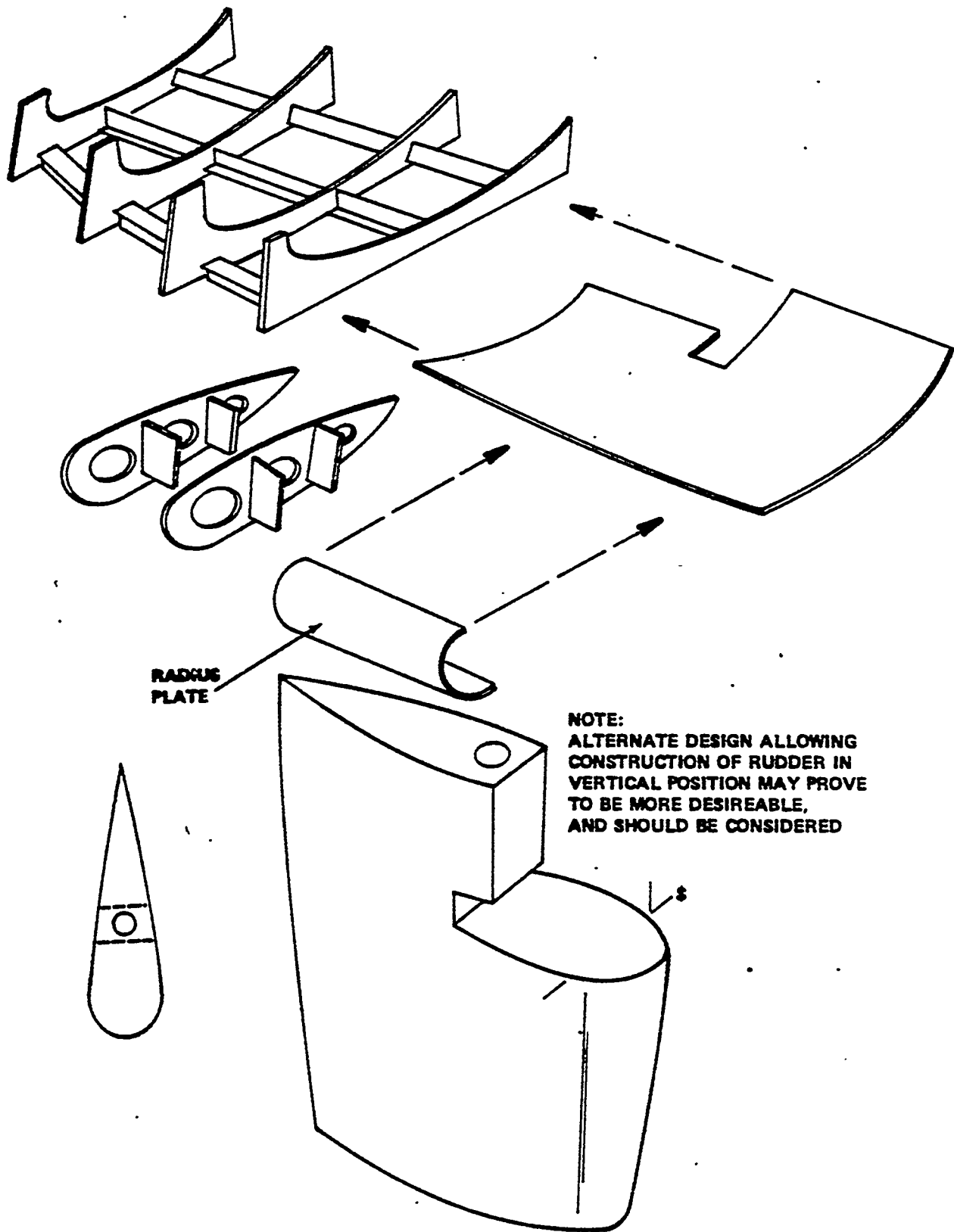


Figure 7-19. Rudder Fabrication Fixture

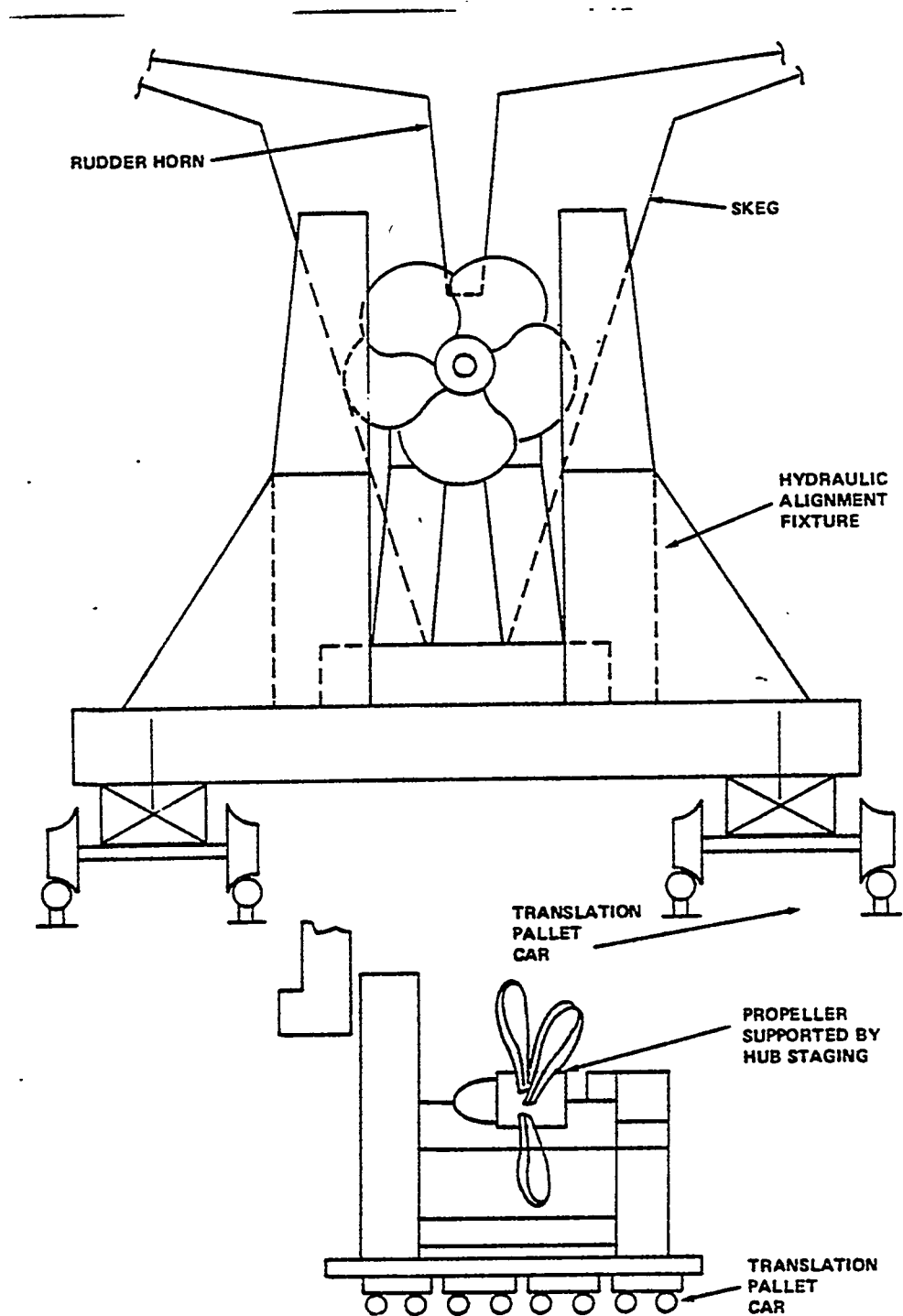


Figure 7-20. Propeller Installation Fixture

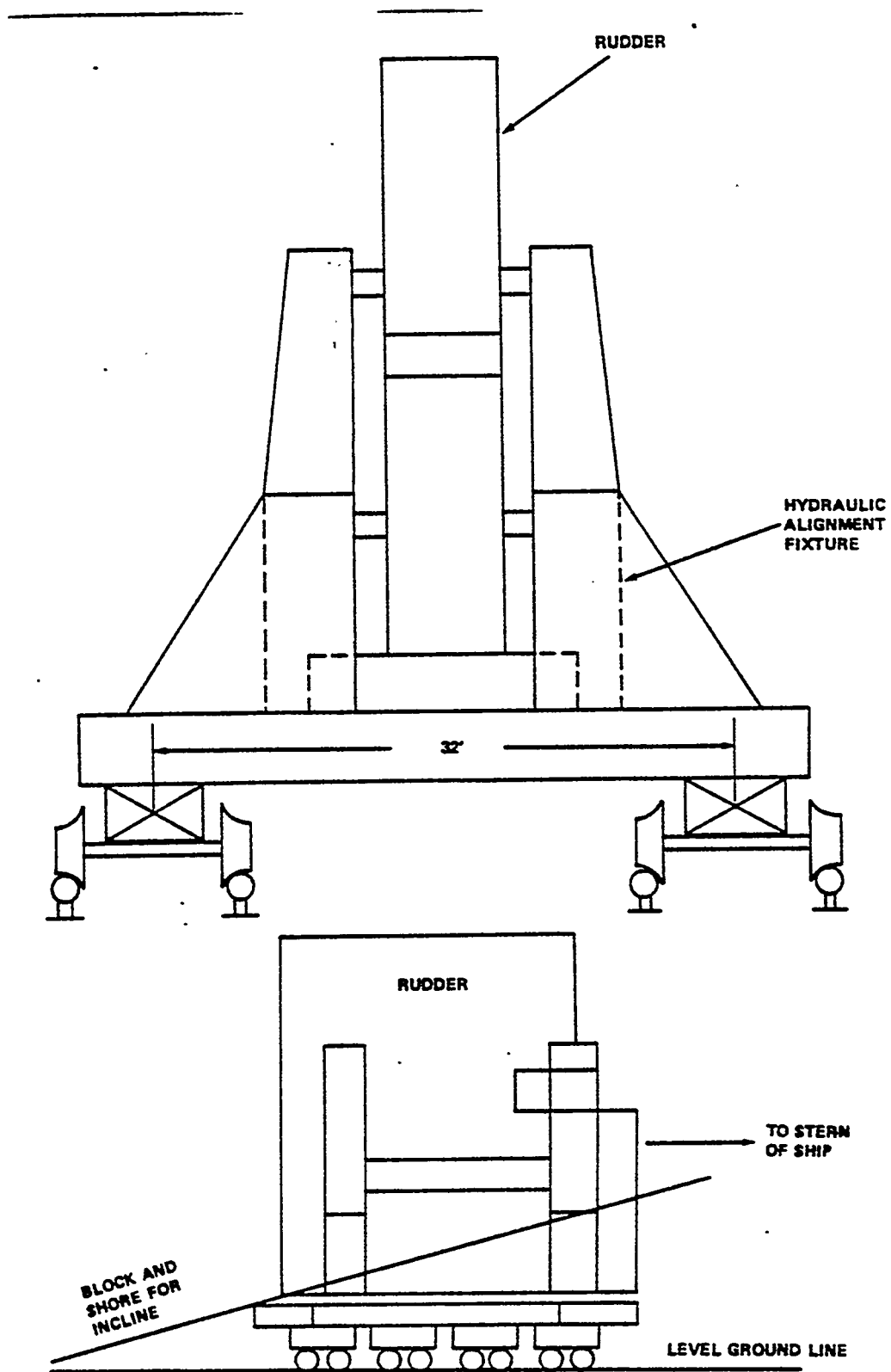


Figure 7-21. Rudder Installation Fixture

## 7.7 SUMMARY AND CONCLUSIONS

1. The non-marine industries, over the years have developed, tried and proven, the cost effectiveness, and production increases to be attained, by applying the use of jigs and fixtures to the repetitive production process. The results of reviewing and analyzing these methods indicate a definite advantage to be derived, when applied to shipbuilding in general. Reference:

- (a) 7.2.1 Dollar lines for dimension control
- (b) 7.2.2 Design for product growth

However, the" primary potential advantage to be attained, and the cost reduction to be realized, from the use of jigs and fixtures, is when applied to the series production, of the same class of ships. Reference:

- (c) Egg crate jig cost, page 19
- (d) Welding fixture cost estimate, page 21
- (e) Special tooling cost summary, page 23
- (f) Single ship production processes without fixtures, page 24
- (g) Series ship production process with fixtures, page 25
- (h) Table 7-1, page 26

From the comparison drawn, between building one assembly for 10 ships by the conventional method without-jigs and fixtures, and by the Series Production process utilizing jigs and fixtures, we find that savings of \$53,574.00 for this one assembly are realized.

2. Shipbuilders are encouraged to develop an increased amount of communication with non-marine industries. The interchange of ideas and technology would be of mutual benefit, and the potential in terms of reduced production costs appears to be considerable.

The use of jigs and fixtures, in order to be the most effective for series production, should be started in close association with the production planning effort. The planned use of these production tools should also be included in the development of the stationization and manufacturing plans, as outlined in Volume III, Part 1.

4. In addition to an early start for the planning of jigs and fixtures, this effort should be the responsibility of a specialized tooling design group, working in cooperation with the production dept. To accomplish this effort by use of production personnel, places an excessive drain on the manufacturing capability.
5. Where practical, jigs and fixtures should be developed so as to allow their use on future anticipated programs, as well as to suit the needs of currently existing requirements.

**VOLUME I I I**

**PART 8**

**MACHINES**

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## **V OLUME III**

### **PART 8**

#### **MACHINES**

##### **8.1 INTRODUCTION**

The series production of 150, 000 DWT tankers requires huge quantities of identical parts and pieces that are best mass produced. In recognition of this fact this part of the study was directed toward determining the feasibility of acquiring high production specialized machines to produce these items. From the machines that were considered three were selected, evaluated and reported on in detail. An in-depth cost comparison was made between fabrication by the manual method and the machine method of the same items.

Note: The data, operational methods, cost figures, and production rates were gathered by the Research Program Staff, from Ingalls Shipbuilding, and during visits to other shipyards that are participant ing in the MarAd R&D program. Tethnical specificat ions, operational data and machine costs were obtained from the designers and/or manufacturers of the machines.

Note: The products and systems described here are manufactured by more than one company. The reference to and use of any one company's product for descriptive purposes does not recommend it over that of any other company.

The results of these comparisons and a description of the selected machines are as follows.

## 8.2 STRUCTURAL STEEL

Certain steel shapes required in a bundance in shipbuilding warrant special consideration first because of their higher cost but more importantly because of their non-availability in current markets. These shapes include many T sections in addition to other profiles and web sections discussed below.

Rolled sections, in all configurations are seldom available today from the steel mills, and are becoming more and more difficult to purchase. Small rolled T-sections are available on the west coast, but not eLsewhere in the U.S. The bulb section, a European rolled section, well suited for tankers, is not made in the U.S. Shipyards are forced by necessity to improvise, and in most cases to fabricate stiffener sections as required.

Larger T- sections, 36 inches or more, can be obtained by stripping a flange from a 36 inch I-beam, and scrapping the flange. Many ship yards are making their large T-sections in this manner. But even when T-sections smaller than 18 inches are needed, they are also obtained by stripping the flanges. This procedure has come about because T-beams with small enough flange and web thickness es are not available as a standard item.

Rolled angles of most required sizes can be purchased. Angles can also be stripped from channels without waste. Shell angles, with a very small height-to-width ratio, however, are not awilable as standaed items and must be fabricated.

### 8.2.1 Fabrication Options

After stripping web and flange stock from plate of the desired thickness, there are three ways to fabricate tees and angles:

- a. Clamp the pieces in a jig, and manually weld using the stick electrode method. This method is the slowest and most costly.
- b. Clamp the pieces in a jig, fit and tack weld them, and then finish weld using an automatic welder. This method is faster, and produces a more uniform section, but each item is "custom made."
- c. Use a specialized T-beam fabrication system designed to produce a specific item in high volume

### 8. 2.2 Automated Fabrication

The fabrication within the ship yard facility of virtually all T sections and L sections by means of automated systems designed for the purpose was analyzed from the standpoint of cost effectivity and practicality. The automated system manufactured by Ogden Engineering Corporation of Schereville, Indiana, was selected as a basis for the analysis. The machine holds two pre-cut pieces accurately in position and moves them at a controlled rate past the welding station where the two are joined. The machine will also straighten the finished product if necessary as it leaves the last station. One machine in current use produces an average of 1990 linear feet of L/T section per 8-hour shift. The Ogden machine is operated by one man, with a typical set-up time of 15 minutes and a typical welding speed of 36 inches per minute. The machine fabricates L sections and T sections in one pass, or I sections,

channels and H sections in two passes. The machine accommodates section heights from 4 to 48 inches and flange widths from 4 to 36 inches for tees and 4 to 48 inches for angles; modifications are available for increasing section heights to 72 inches.

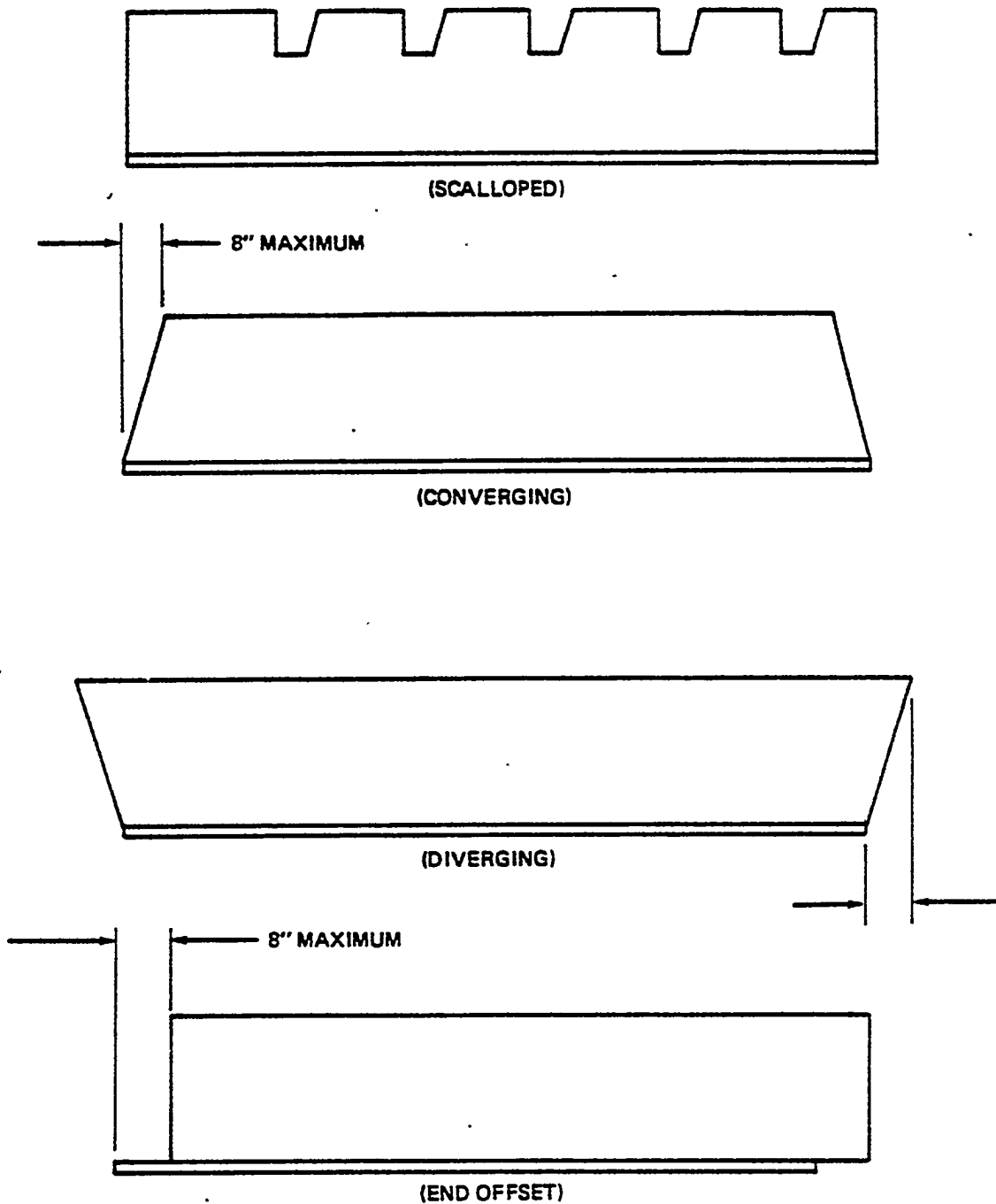
### 8. 2.3 L/T-Beam Machine Capacity and Specifications

#### a. Machine Capacity

- (1) The L/T machine is capable of manufacturing T or L sections from two pieces of flat, burned, sheared, or rolled plate. Completed I-sections can be manufactured from T-sections by rotating the T's, adding a flange, and recentering the machine for a second pass. When manufacturing I-sections, it is not necessary that both flanges be either the same thickness or the same width.

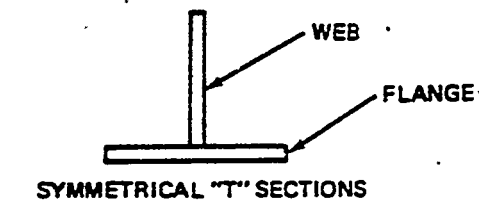
The maximum and minimum flange and web dimensions, as well as the various beam configurations that this machine can handle, are illustrated in figures 8-1 and 8-2.

- (2) The machine can fabricate L or T sections according to the following schedule:
  - (a) The maximum height overall for an L or T section is 48 inches. Example: A web height of 46 inches and a flange thickness of 2 inches. As an option, the machine can be equipped to fabricate T or L sections up to 72 inches.

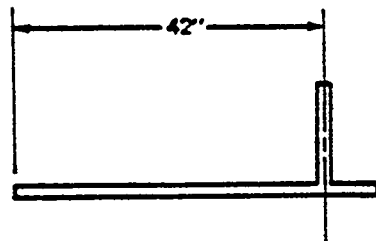


MACHINE CAN PROCESS ALL OF THE SECTIONS SHOWN AUTOMATICALLY IN EITHER DIRECTION IN ADDITION TO ANY COMBINATION OF EACH CHARACTERISTIC WITHIN LIMITS SHOWN.

Figure 8-1. Characteristics of "T" and "L" Sections (Sheet 1 of 2)



FLANGE WIDTH-	4" TO 36"	
FLANGE THICKNESS-	1/4" TO 2"	
WEB DEPTH-	4" TO 46"	4" TO 72"
WEB THICKNESS-	3/16" TO 2"	



SYMMETRICAL "T" SECTIONS  
(ANGLES OR "L" SECTIONS)

WEBS MAY BE LOCATED ANY DISTANCE UP TO AND INCLUDING 1/2" FROM ONE EDGE OF THE FLANGE. PROVISIONS ARE MADE FOR HANDLING BOTH RIGHT AND LEFT HAND SECTIONS UP TO 4" ( ) OFF-SETTING ON BEAMS WITH FLANGES 18" ) AND UNDER. WHEN FABRICATING ANGLES OR L-SECTIONS, FLANGE CAN BE LOCATED UP TO 42" OFF-SET FROM CENTER LINE ON ONE SIDE ONLY.

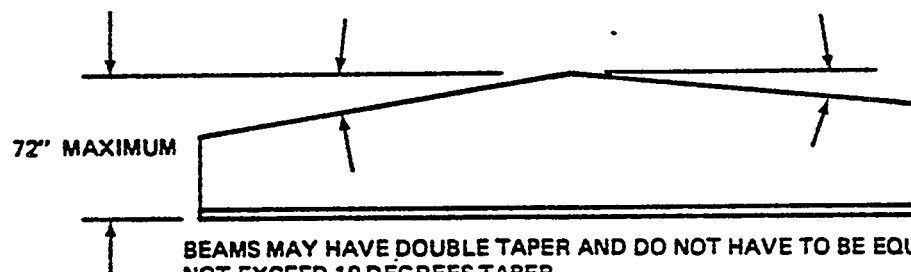
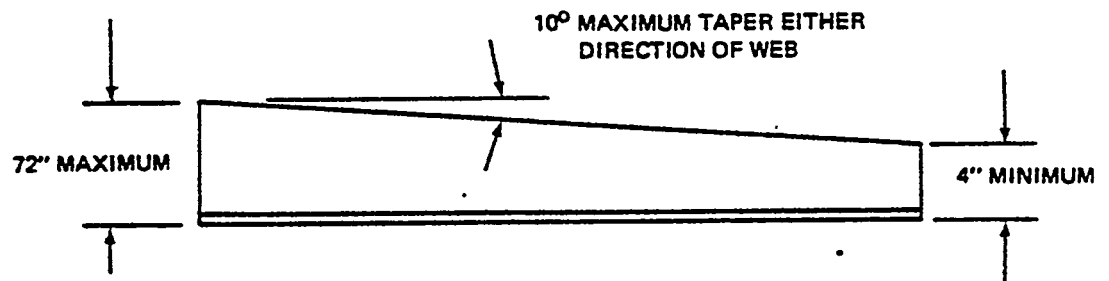
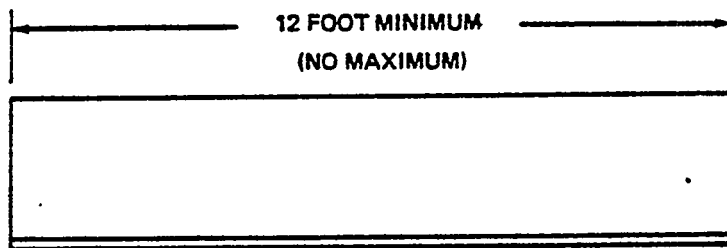


Figure 8-1. Characteristics of "T" and "L" Sections (Sheet 2 of 2)

- (b) The minimum height is 4 inches.
- (c) The maximum flange width for L sections is 42 inches.
- (d) The maximum flange width for T sections is 36 inches.
- (e) The minimum flange width for L or T sections is 4 inches.
- (f) The maximum web or flange thickness is 2 inches, minimum is 1/4 inch.
- (g) The maximum weight of any fabricated section cannot exceed 500 pounds per foot.
- (h) The machine is fully capable of processing all types of steel although additional welding procedures must be established for each type.
- (i) The machine is capable of starting or stopping the weld at the very end of the beams. No tack welding is required.
- (j) The flange and web centering devices can be adjusted within 15 minutes when changing from T's to L's or changing plate sizes without using special tools.

#### 8.2.4 Machine Operation (Three Stations)

##### a. Station I - Input Alignment Fixture

- (1) The flange and web plates are supplied by the conveyor system into the input side of the machine and advanced until they hit stops. As the material is moving through, a flange alignment roller is activated to position the flange. To align the web end flush, forward or behind, the flange, a hydraulic operated web positioner moves against the web and moves it forward or reverse until the exact location is satisfied. When satisfied, an upper web clamp lowers from the material allowing the operator to start the drive and advance it to Station II.
- (2) The drive roller at the input alignment fixture drives against the bottom of the flange while pressure is applied on top of the web.
- (3) When the input alignment station is being operated at welding speeds, its drive mechanism is synchronized with the speeds of the other two drives of Station II and III.

##### b. Station II - Weld Station

- (1) As the material enters Station II, a second flange positioner roller moves against the flange, and an input welding ground shoe lifts from underneath. When the material reaches the welding zone, the input alignment drive is stopped, an upper web clamp is lowered to hold the web, and a web positioner

moves in to hold the web perpendicular to the flange. The operator now drops the welding flux and starts the welding cycle. After the weld arcs start, a flux recovery system is activated to recover the unfused flux.

- (2) The material is driven through the welding zone by a hydraulic motor with a harmonic drive speed reducer. The speed is variable and is synchronized with the speed of Station III.
- (3) Station II table carries the floating guidance mechanism, the welding torches, one ground shoe assembly, the main drive mechanism, and a flange positioning mechanism.

c. Station III - Post Weld Flange Straightener

- (1) When the welded beam enters Station III, a second welding ground shoe activates against the flange, a third flange positioner roller moves in, and a third vertical web clamp drops to hold the web. (At this point, the input welding ground shoe and flange positioner rollers from Station I de-energize and are ready to receive-material for the next beam.) Station III drives the finished beam onto the outgoing conveyor.
- (2) This station will straighten T flanges transversely after the welding heat has pulled them to less than 90 degrees with the web. The sections are driven through the straightener at the synchronized welding speed. The fixture can be adjusted for straightening

flanges up to 1 inch thick. Thicker flanges, will not require straightening.

- (a) The maximum flange width that can be straightened is 36 inches.
- (b) If a beam requires flange straightening, two hydraulic operated pressure rolls are lowered against each side of the flange. Hydraulic pressure is applied and actually bends the flange down until the pressure rolls hit a predetermined stop. This is accomplished as the beam is being driven through Station III.
- (c) A hydraulic driven motor with a harmonic drive speed reducer is used to pull the flanges through this fixture. The speed is synchronized with the drive at Station II.

#### 8.2.5 Welding System

- a. The welding process is tandem submerged arc with the capability of using one or two arcs per fillet, depending upon the fillet size and speed requirements. Two fillets are made simultaneously.
  - (1) The maximum fillet size per pass is 3/8 inches. The arc arrangement will be DC-AC.
  - (2) For triple arc (optional), a DC or AC arc can be supplied to fit existing equipment.

- b. The maximum wire size is 5/32 inches.
- c. Welding speeds are variable from 10 to 100 inches per minute. Welding is possible in one direction only.

### 8.3 COST COMPARISON BETWEEN MANUAL METHOD AND AUTOMATED METHOD

#### 8.3.1 Established Parameters

- a. The tasks to be accomplished is to fabricate T-beam stiffener sections (hereafter referred to as "units"), for the midbody of a 150,000 DWT tanker to be produced in series production.
- b. Due to standard design the units are all 48' long.
- c. There are 1280 units per ship midbody.
- d. Inasmuch as the welding speed of the machine is 0 to 100 in. P/M, and the manual method is 0 to 30 in. P/M depending on the fillet weld size, 36 in. P/M is established for the machine and 12 in. P/M average speed for the manual method.
- e. A nominal labor cost for both methods is established at \$10 per m/hr.
- f. The machine requires one operator. The manual method requires a 4-man crew per work station: (1) fitter, (1) tacker, (1) welder, and (1) materials handler.

- g. The estimated time in manhours, and operations required to fabricate one 48' unit by the machine method is outlined below:

Operation	Time
Set-up	.12 m/hr
Position and clamp	.01 m/hr
Weld	.26 m/hr
Total Time	.39 m / h r

- h. This total (.39) times 8 hours (one shift), rounded off to the nearest whole unit, equates to a single shift production rate of 20 units for the machine method. The man/hr cost of .39 is operating time only. The depreciation schedule, as shown in Table 8-1, page 8.14, increases the fabrication cost of one unit, by the machine method to \$7.73.
- i. The estimated time in man/hrs, and the operations required to fabricate T-beams by the manual method, are shown in Table 8-2, page 8-15. The depreciation schedule shows the fabrication cost per unit by the manual method to be \$48.70.
- j. Multiplying these costs by the number of units required per ship midbody (1280) the cost of fabrication per ship by the manual method is \$62, 336. By the same equation the machine method cost is \$9,894. The cost savings per ship is \$52,442.
- k. Given a series production contract of (six) ships, 7680 stiffener sections would be required. To fabricate these units by the two methods is:

Manual Method	\$374,016
Machine Method	59,366
Cost Savings for 6 Ships	\$314,650

The capital investment in the machine would be recovered on the sixth ship.

1. The production rate of the machine is (20) units per shift, and the production rate of a four man crew is (6.5) units per shift. Four crews or 16 men would be required to equal the machine production rate.

#### 8. 3.2 Discussion L/T Beam Machine

The initial cost of the machine will by far exceed the cost of equipment for the manual method, \$300,000 vs. \$9,300. Higher capital expenditures are to be anticipated when modernizing a facility.

However, over a series of ship production, in this case six ships, the benefit from investing in machines such as the L/T beam fabricator will more than off set the. initial capital outlay (i. e. , \$52,518 per ship midbody on the subject tanker).

An intangible benefit to be derived from the L T beam machine is that fewer craftsmen are required for the machine method (i. e. , 1-1 /2 men vs. 16 men). This would be particularly advantageous to a shipyard engaged in series production, as the accelerated production would increase the demand for skilled craftsmen.

#### 8.4 PIPE FABRICATION

Based upon results of studies made in support of other sections of this report, the man hours required to fabricate and install the piping systems is 12% of the total ship construction man hour costs. This does not include the cost of materials and/or equipment. In addition to the cost of fabricating and installing the piping systems, no other facet of shipbuilding is more demanding and/or requires craftsmen

Table 8-1

## COMPARISON OF MACHINE VERSUS MANUAL TEE BEAM FABRICATION

Tee Beam Fabricator	Manual
<p>For Series Production of (6) Ships</p> <p>20 Stiffeners Shift      1280 Stiffener</p> <p>Sections per Midbody - 750 per Contract</p> <p>Budgetary Cost of Machine      \$300,000</p> <p>Economic Life      18 yrs</p> <p>Annual Depreciation      16,000</p> <p>Maintenance Part      2,000</p> <p>Labor 1/2 Man Yr      10,200</p> <p>Operators 1-1/2 Man Yrs      31,200</p> <p>TOTAL      \$ 59,400</p> <p>Fab. Cost Per Stiffener \$7.73</p>	<p>7 Stiffeners/Shift x 4 men      (1,820) yr</p> <p>Work Grid      \$ 1,000</p> <p>Two Jib Cranes at 3K      6,000</p> <p>Tractor Type Welder      1,200</p> <p>Arc/Welder      800</p> <p>Budgetary Cost      9,000</p> <p>Economic Life      15 yr</p> <p>Annual Depreciation      600</p> <p>Hand Tools      300</p> <p>Maint. Parts      500</p> <p>Maint. Labor 1/5 Man Yr      4,160</p> <p>Crew Labor (4) Men      83,200</p> <p>TOTAL      \$88,760</p> <p>Fab. Cost Per Stiffener \$48.70</p>

Table 8.2  
COST ESTIMATE - TEE BEAM FABRICATION BY THE  
MANUAL METHOD

1.	Set -Up Time	
	a. Materials Handling (Crane) Load (1) Web and (1) Flange on Work Area	10 min
	b. Fit and Tack	20 min
	c. Set-Up Track for Tractor Type Semi-Automatic Welding Machine	15 min
	d. Set-Up Machine (2 fillet weld heads), Start and Check	10 min
2.	Process Time	
	a. Weld 48' - 0" (576" @ 12" rein)	48 min
3.	Remove Machine and Track	
	a. Stop machine, remove machine from tracks, adjust leads	15 min
	b. Remove track	15 min
4.	Move "Tee" Beam to Storage Location	10 min
5.	Summary	
	Total Lapsed Time = 143 min	

143 x 4 man crew = 572 min or 9.53 m/hrs which is the labor cost if only one stiffener is fabricated. For the 2nd and subsequent units, the welding process becomes the controlling factor for production output, and operations 1.a, b, c, 3.b + 4 are repeated, concurrently with the welding of the previous unit(s).

The welding process time (48 min) PLUS 25 min for machine change is 73 min per stiffener unit. One shift (6 hrs) is 480 min divided by 73 equals 6.57 stiffeners per shift. 4 men x 8 hrs = 32 m/hrs expended per shift. 32 divided by 6.57 equals 4.97 m/hrs per stiffener unit for one shift production. 4.97 m/hrs @ \$10.00 per/hr is \$49.70 labor cost per unit, by the manual method.

of higher manual skills than the more critical piping systems, such as steam, fuel, and lube oil, and in cases where the ship is propelled by gas turbines, the bleed air system where temperatures can reach 1000 deg F.

#### 8.4.1 Discussion - Pipe

Pipe fabrication in many shipyards, generally speaking, with the exception of bending, is a manual process supplemented in varying degrees with portable and semi-portable hand held power tools. Pipe welding techniques have been improved and more productive with the development of semi-automatic and automatic pipe welders.

There are also pipe cutting and edge preparation machines available that will provide edge preparations suitable for automatic welding of pipe.

There have been advances in the development of pipe bending machines to provide bending capacity that preclude and renders obsolete the process of "hot bending" of heavy wall, large diameter pipe. These heavier machines are currently being put to effective use in U. S. shipyards. Results of this study indicate that with few exceptions these machines are manually controlled, step-by- step throughout the bending sequence and are dependent upon operator skill. Preliminary investigations indicate that several companies are developing, and in some instances have developed, numerical control units and systems that fully automate the pipe bending process. It is strongly recommended that more detailed studies be made on this subject.

Two facets of pipe fabrication were investigated in detail and the findings are as follows:

#### 8.4.2 Automatic Pipe Welders

The automatic pipe welding system to be described in this report is designed and produced by:

The Astro-Arc Company  
11144 Penrose Street  
Sun Valley, Ca 91352

##### a. Description and Operation

The principal units of this system are the:

E-300-P pulsed current power source (Figure 8-3)  
AM- 11 Welding Head (Figure 8-4)  
AV-2 Welding Head (Figure 8-5)

The welding process is TIG.

The AM- 11 is most suited for all pipes in the range 2 inch to 42 inches and larger, while the AV- 2 pipe welding head is designed for minimum radial (5 inch) clearance requirements in the welding of 1/2 inch to 8 inch pipe with standard carriages and larger diameters with special carriages. The manufacturer will modify either unit to meet specific requirements. Both heads are designed for continuous use under field conditions.

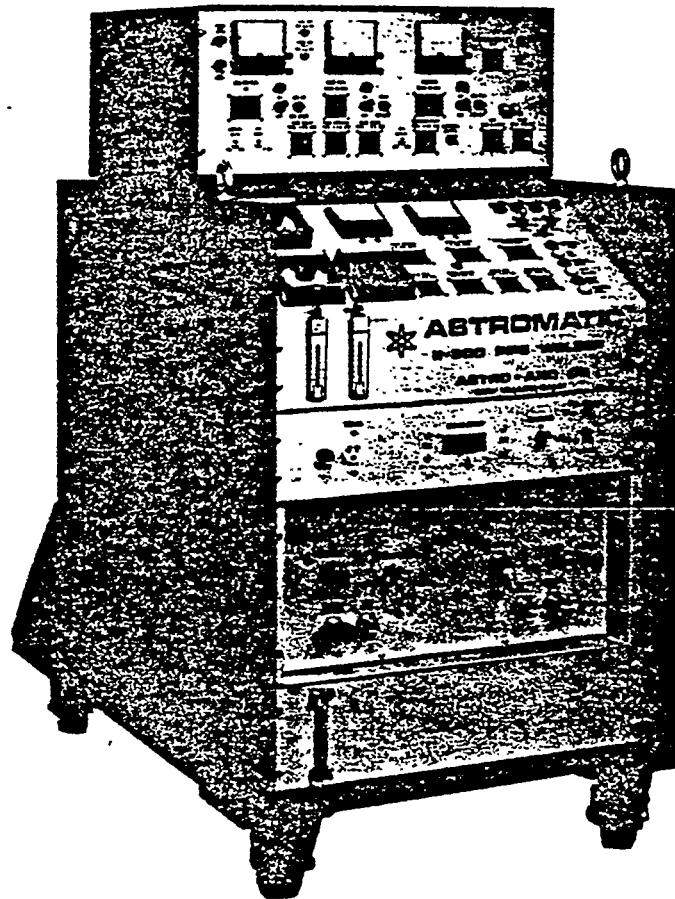


Figure 8-2. Astromatic E-300-P Power Source

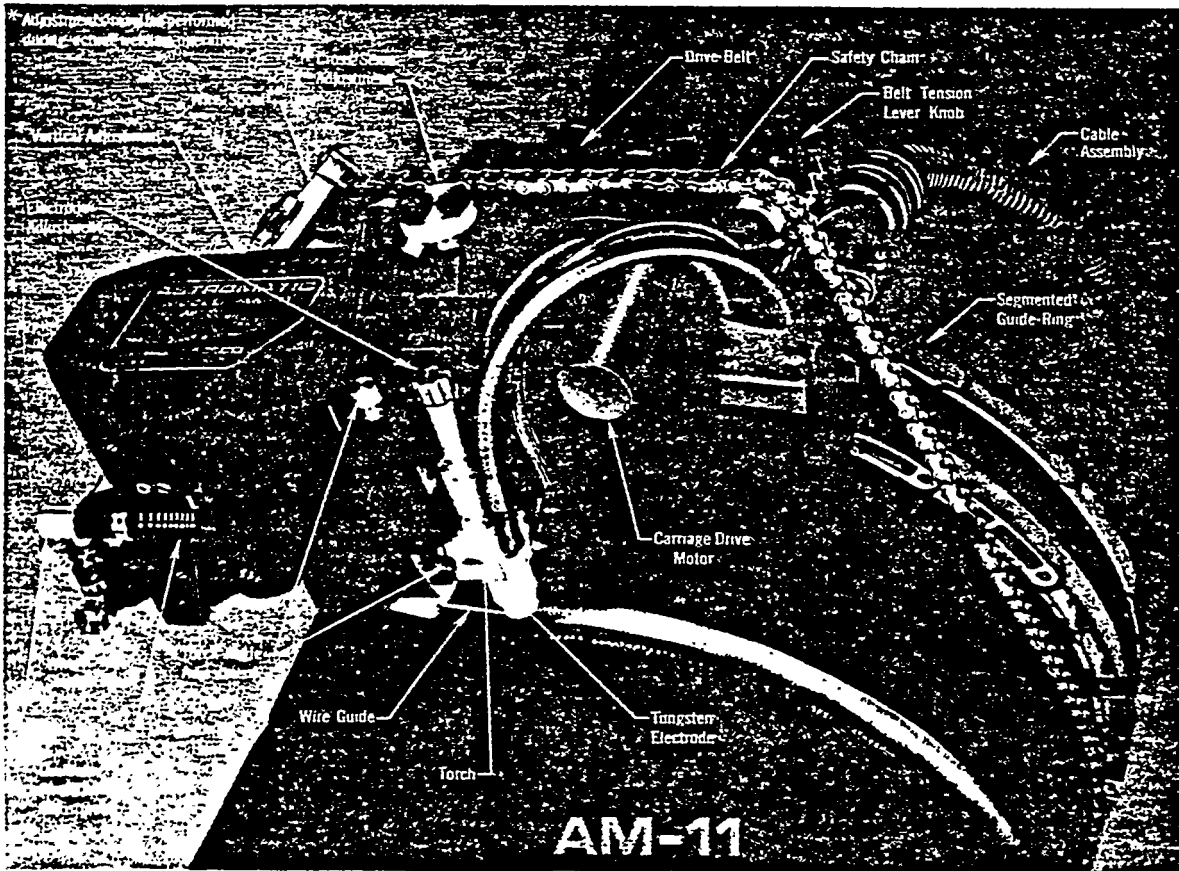


Figure 8.3. AM- 11 Welding Head

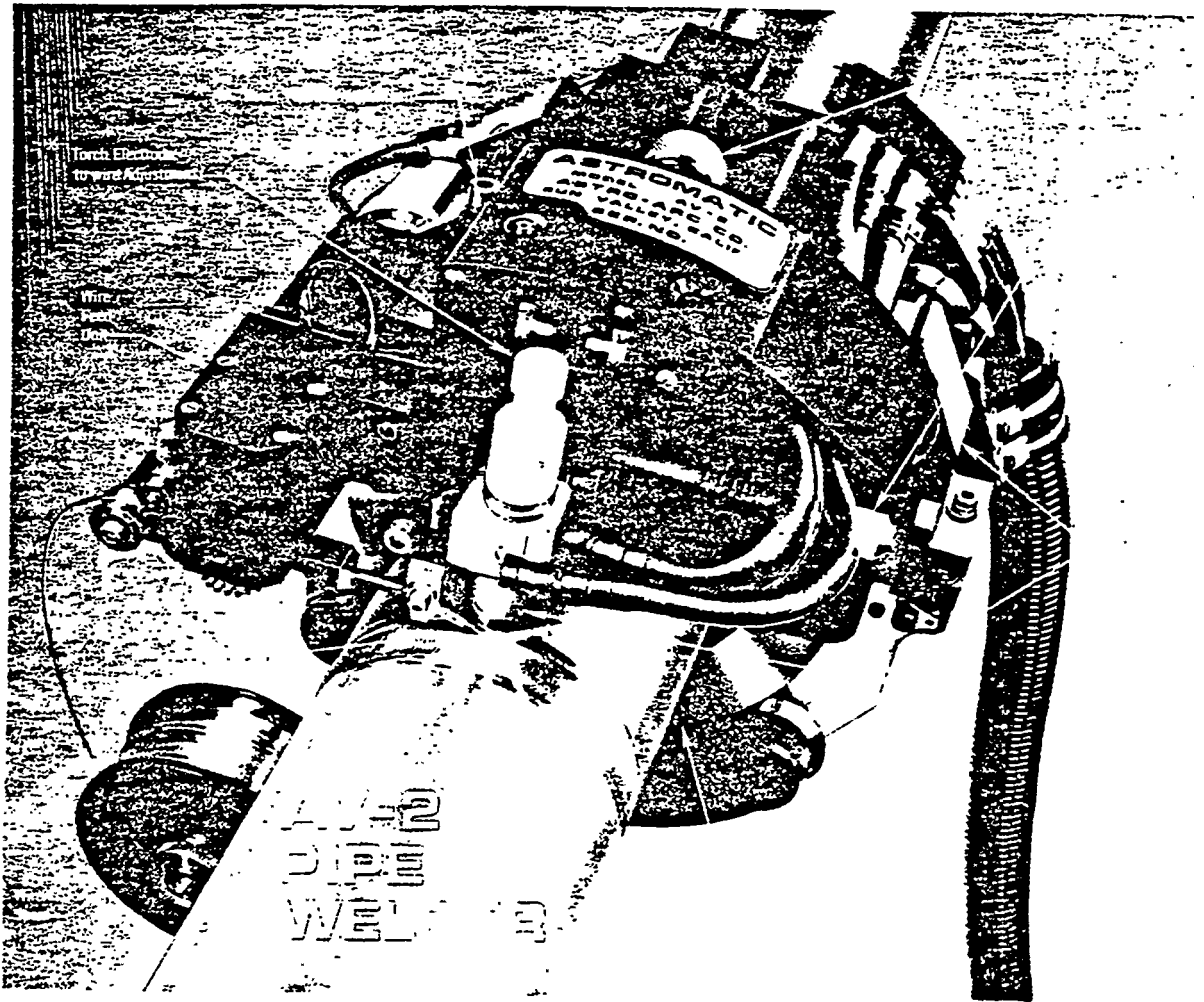


Figure 8-4. AV-2 Welding Head

Both heads have built-in dwell type oscillator and AVC controls. Weld metal is supplied from a motor driven, 4 inch standard spool.

The welding heads can be changed in less than ten minutes and each head is guided around the pipe joint by segmented belt guide rings. The dwell time at oscillator excursion limits is independently adjustable. The machine is equipped with direct reading control settings and the welding heads are designed to provide a clear view of the weld zone. To compensate for uneven wall thickness, off- set joints, uneven lands, and weld bead sag, a manual override and/or adjusts can be made without inhibiting the automatic process. Table 8-1 lists specification data on the AV2 and AM11.

#### b. Options

The automatic welding system includes an optional item that permits the unit to be used in remote locations such as aboard ship for piping installation (figure 8-6). In this application the power source can be positioned on the main deck or other suitable location and fully automated welding of field joints can be accomplished at distances up to 200 feet from the machine.

### 8.5 TRI- TOOL PIPE CUTTING AND BEVELING MACHINE

One of the requirements for all automatic welding processes is an edge preparation of highly uniform quality. Most automatic welding systems will tolerate and compensate for a limited amount of variation in the root gap and/or imperfections in the welding edge, but to obtain the best quality welds and maximum productivity from the system a machined edge preparation while not mandatory, is

Table 8-3. Specification Data on Pipe Welding Heads

Specifications	AV2	AM-11
RANGE OF PIPE SIZES (OTHER SIZES ON SPECIAL ORDER)	½" to 8"	2" to 42"
PIPE WALL THICKNESS, MAXIMUM	1¾"	3"
AVC TRAVEL RANGE, AUTOMATIC	1"	1.25"
AVC HEAD VERTICAL ADJUSTMENT, MANUAL	1"	2.25"
AVC COMPENSATION SPEED, APPROXIMATE	60 IPM	60 IPM
ELECTRODE-TO-WIRE ADJUSTMENT, MANUAL	0.25"	0.25"
WIRE POSITIONING, MANUAL	Three Dimensional	Three Dimensional
WIRE FEED SPEED	5 to 100 IPM	5 to 100 IPM
WIRE FEEDER SIZE RANGE, DIA.	0.020" to 0.062"	0.020" to 0.062"
WIRE SPOOL SIZE	4" Dia.	4" Dia.
CARRIAGE TRAVEL SPEED (WELDING SPEED)	2 to 40 IPM	1 to 20 IPM
CROSS-SEAM ADJUSTMENT RANGE, MANUAL	±0.375"	±0.75"
OSCILLATOR AMPLITUDE RANGE, CONTINUOUSLY VARIABLE, MANUAL	0 to 0.5"	0 to 1"
OSCILLATOR FREQUENCY, CYCLES PER MINUTE	20 to 100	20 to 100
OSCILLATOR DWELL TIME, INDEPENDENTLY ADJUSTABLE FOR EACH SIDE	0.1 to 1.9 SEC	0.1 to 1.9 SEC
TORCH TILT RANGE, MANUAL	Optional	±17°
CURRENT CAPACITY, CONTINUOUS	300A	300A
RADIAL CLEARANCE REQUIREMENT	5"	7½"
WIDTH CLEARANCE REQUIREMENT, OVERALL	12"	13½"
LENGTH OF STRAIGHT PIPE REQUIRED FOR MOUNTING, FROM WELD &	8"	8"
CLOSEST APPROACH TO UPRIGHT OBSTRUCTION, FROM WELD &	1"	2.5"
WEIGHT, LESS CABLES, GUIDE RING AND WIRE SPOOL	20 Lbs. Approx.	18 Lbs. Approx.

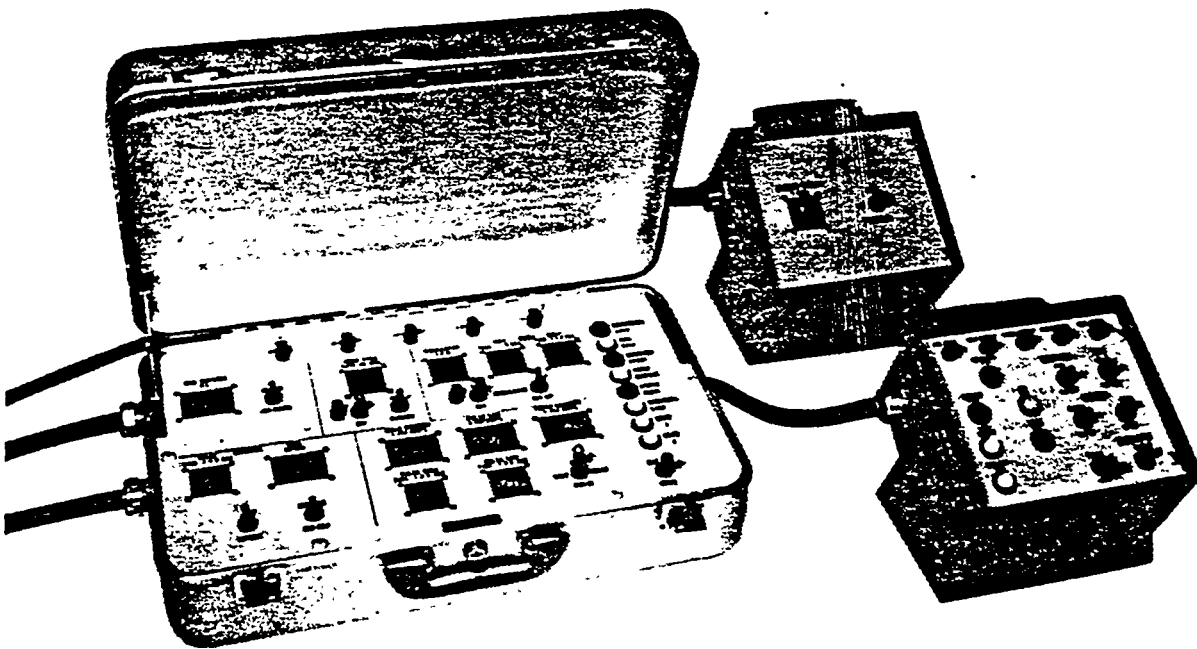


Figure 8.5. Remote Operator's Pendant Control

highly desirable. This requirement holds true in pipe welding in general, but especially so on pipe to be used in Class I piping systems.

#### 8. 5.1 Description

There are several types of pipe beveling tools on the commercial market. The one to be described and illustrated here is designed and manufactured by:

The Tri-Tool Corp  
4505 Green Stone Road  
placerville, Ca. 95667

The Tri- Tool pipe cutting and beveling units are a family of machines that when viewed as a group will cut and bevel pipe of most commonly used alloys of up to 12 inches in diameter and schedule 160 wall

thickness. The 12 inch diameter limit is utilizing standard tools. Units to bevel pipe of larger diameters can also be provided by special orders.

A description and an illustration of each of the units follows.

#### 8.5.2 Model 702 Cutter/Beveler

Cuts and bevels 1 in. to 4 in. diameter  
Time: 1 minute per inch of diameter  
Figure No. 8-7

#### 8.5.3 Model 703 Pipe Beveler

Bevels pipe 1-1/2 inch through 4 inch diameter and schedules 10 through 160  
Makes 37Y2 deg bevel with or without land and will J bevel  
Time: 1 minute per inch of pipe diameter  
Figure No. 8-8

#### 8.5.4 Model 704 Pipe Beveler

Bevels pipe 1/2 inch through 1 inch manually operated  
Time: approximately 2 minutes  
Figure No. 8-8

#### 8.5.5 Model 708 Pipe Beveler

Will bevel, cut land, counter bor 6 inch and 8 inch pipe, schedule 40 through schedule 160, in one operation  
Time: 1 minute per inch of pipe diameter  
Figure No. 8-8

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#### 8.5.6 Model 712 Pipe Beveler

Will bevel, cut and counter bore 10 inch through 12 inch pipe, all schedules, in a single operation

Time: 1 minute per inch of pipe diameter

Figure No. 8-8

#### 8.5.7 Summary (Pipe Fabrications)

As in most modern developments there are certain restrictions and/or limiting factors involved when replacing an existing manual method with high production automatic and semi-automatic machines and systems. In the instance of the automatic pipe welding systems, the penalty is that a better fit-up and edge preparation is required, but in retrospect, the same improvement would be equally beneficial to the manual method.

The edge preparation tools heretofore described are an ideal "companion" family of tools to be used in conjunction with the automatic pipe welders in order to take full advantage of the quality and production capabilities of the system.

The beveling tools, as can be seen in the illustrations, are completely portable and can be used to equal advantage in the shop for production runs, or aboard ship for field joints.

### 8.6 SHEET METAL

While sheetmetal admittedly is not a major item of cost in building large tankers, it is nevertheless a necessary element in the construction of all ships.

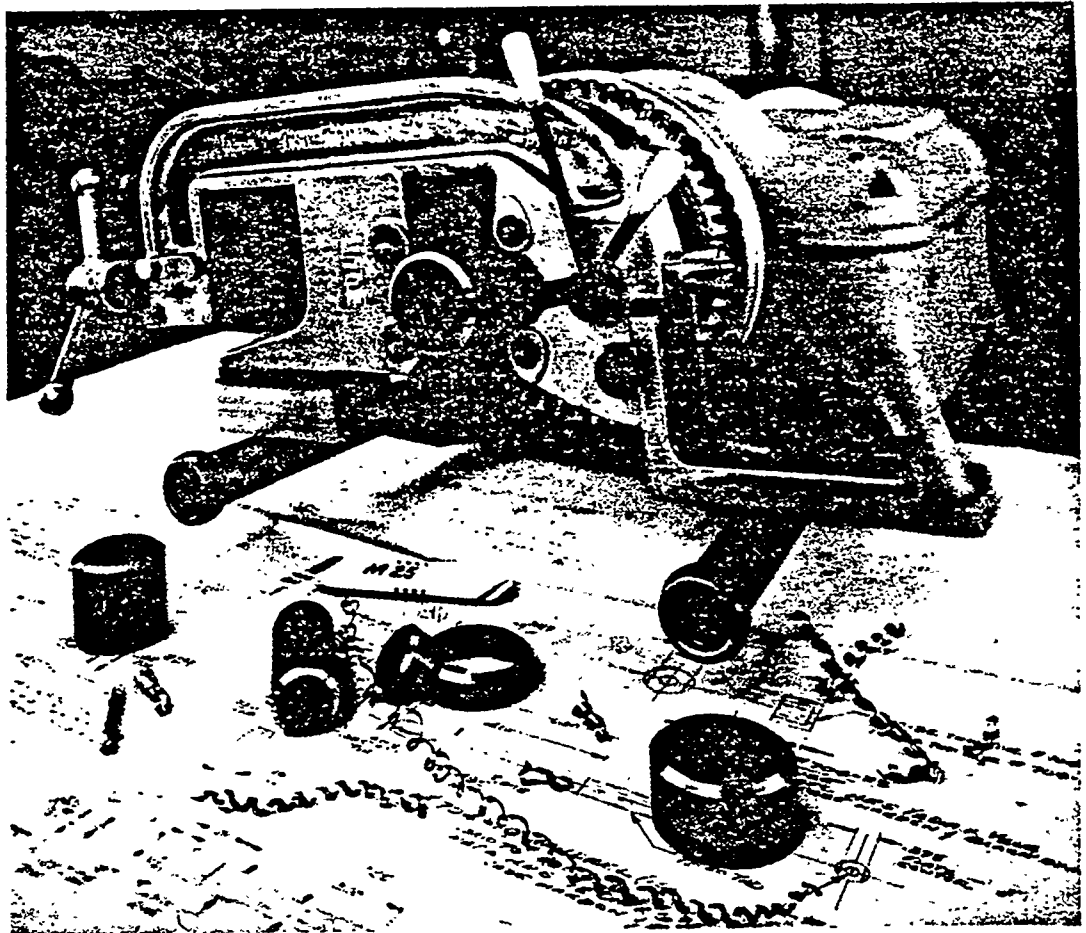
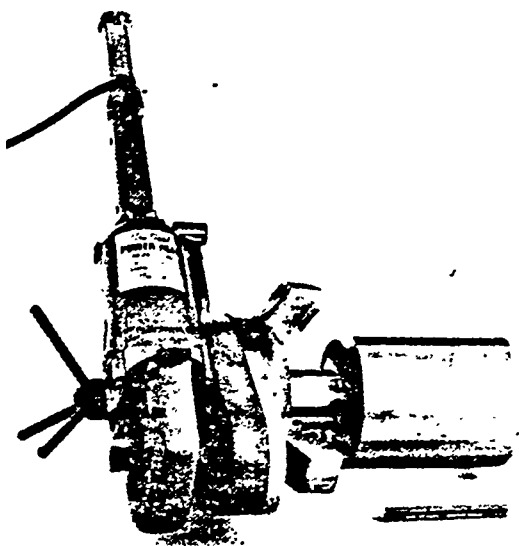
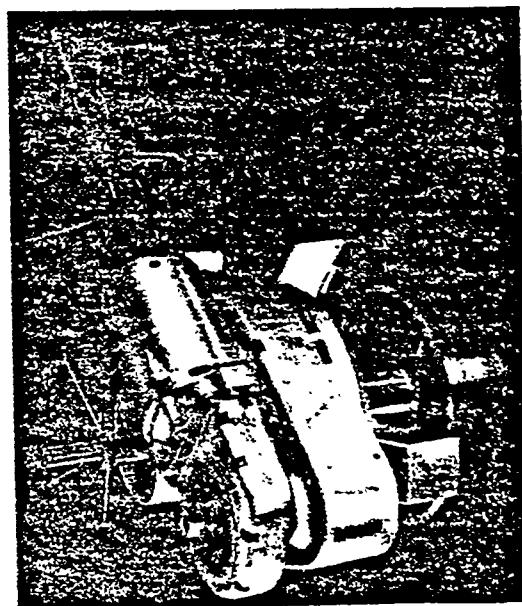


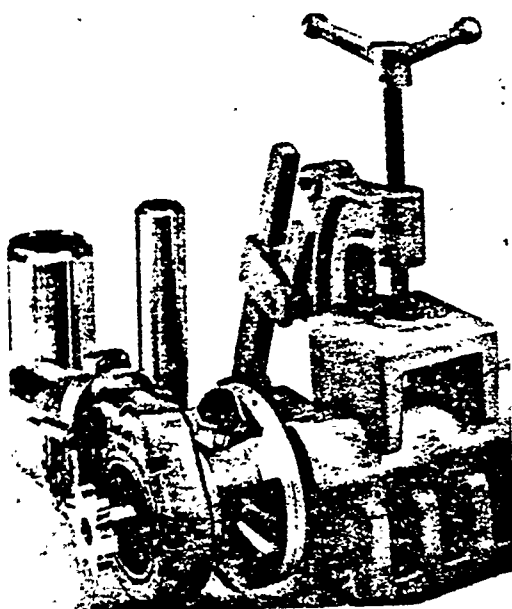
Figure 8-6. Tri Tool Model 702 Pipe Cutter/Beveler



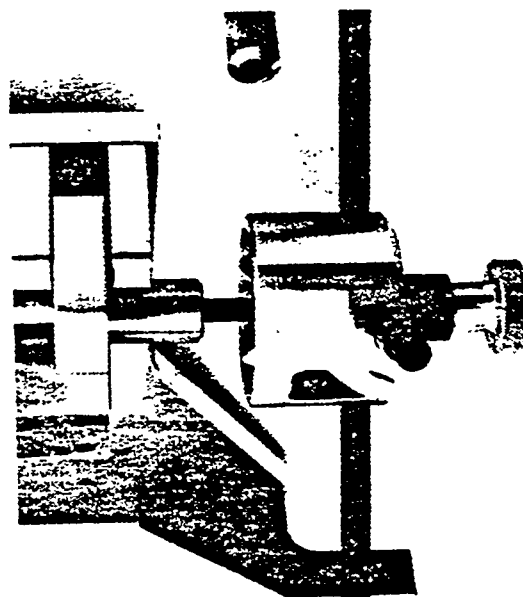
(a) Model 703



(b) Model 704



(c) Model 708



(d) Model 712

Figure 8-7. Models of Tri-Tool Pipe Bevelers for  
Pipe Diameters from 1/2 Inch Through 12 Inches

Moreover, the manhour cost to convert raw sheetmetal to completed parts, pound for pound, can equal or exceed that of structural steel if not accomplished in a cost effective and timely manner. Also, a completion schedule will be just as adversely impacted due to the lack of sheetmetal parts, as it will be, due to a shortage of more costly items.

#### 8.6.1 Discussion (Sheetmetal)

The “state of the art” of sheetmetal fabrication has advanced more rapidly than other disciplines represented in shipbuilding. This is due in part to the fact that sheetmetal is used much more extensively in other industries involved” in high volume and highly competitive production. Many of the machines developed for these other industries can be used in a shipyard without modification while still others may require only slight modification for use.

Three machines that were developed for other industries that are suitable, as is, for sheetmetal fabrication in a shipyard environment, will be discussed here. The “machines, their intended purpose, capabilities, operating characteristics, and a simple cost comparison between the machine and the manual method of fabricating the same product, are given below.

#### 8. 6.2 Wiede-Matic Turret Punch Press

The Wiede - Matic Turret Punch Press is an electro-pneumatically powered, numerical tape controned machine that will cut parts, in the flat pattern, from sheetmetal up to 1/4 inch thick, 50 inch x 148 inch in size (with shift).

The machine requires one operator and will produce an average of 225 parts in each eight-hour shift of operation.

The skill level for an operator is as follows:

- a. The most desirable individual for an operator would be a journeyman sheetmetal craftsman, experienced in sheet-metal parts development and layout, plus years of experience in the operation of normal sheetmetal power tools and equipment.
- b. In the event that the journeyman craftsman is not available on the labor market, the operator can be acquired as follows:
- c. An individual over eighteen years of age, with a high school education, of average intelligence, and mechanical aptitude, can be trained for safe simple operation of the machine in one week.
- d. The same individual can be completely trained in all phases of the Wiede-Matic operations, plus set-up, tool selection, and installation as well as "operator level" maintenance to the machine, in ninety days.
- e. At this point, the employee of ninety days duration who was conservatively 80% productive during his training period, is now 100 percent productive and by utilizing the "specialized" machine can produce an average of 225 parts per day.

In contrast to the above productivity statistics taken from actual files, the training period for a sheetmetal apprentice is a minimum of two years. A journeyman sheetmetal craftsman equipped with standard shop equipment can

produce an average of 8 parts of comparable complexity per eight-hour shift utilizing manual methods of layout, cut and trim.

### 8. 6.3 Capabilities

The machine is capable of flat pattern production of categories of parts which encompass over 95 percent of the sheetmetal parts used in ship construction. These parts listed by category are as follows

1. Round elbows - complete gore generator (except spiral duct)
2. Rect elbows - complete gore generation
3. Flat oval elbows - complete gore generation
4. Rect offsets - complete cheek generation
5. "J" type terminals (body) - complete generation including bolt holes
6. "JA" type terminals (body) - complete pattern in four part including bolt holes
7. "E" type terminals - gore and bell mouth generation
8. Square to square transitions - pattern in two parts
9. Square to round transition - pattern in two parts including center punch of brake lines
10. Round to round transition - pattern in one or two parts depending on size

11. Rect to round transition - pattern in two parts and marking of brake lines
12. Rect to flat oval transition - pattern in two parts and marking of brake lines
13. Round to flat oval transition - pattern in two parts and marking of brake lines
14. Offset transitions:
  - a. Square to square
  - b. Square to round
  - c. Round to round
  - d. Rect to round
  - e. Rect to flat oval
  - f. Round to flat oval
15. "Y" joints round pattern in three parts
16. Rect flanges - complete generation including bolt holes
17. Round flanges - bolt hole pattern and center hole for nibbler use
18. Radius - corner flanges - complete generation
19. Flat oval flanges - complete generation
20. Access plates - bolt hole patterns
21. "L" type frames (round) - bolt hole pattern and center hole for nibbler use

22. " L " type frames (rect) - complete generation including bolt holes

23. Laterals (Round) - pattern generated complete in two parts

A cost comparison between the manual vs. the machine method was made and is presented in tabular form (Ref Table 8-4). The table compares cost per piece of sheet metals produced by manual method vs. the machine method. The result as can be seen in the subject table is \$1.22 per piece by the machine method, and is \$5.62 by the manual method.

## 8.7 TUBE FORMING AND DUCT FORMING

### 8. 7.1 Discussion

The fabrication and installation of sheet metal ducting for the ventilation system of a ship is a time-consuming, tedious operation that requires a specialized craftsman of a high degree of skill and ability. This task is frequently compounded for the following reasons:

1. By usual shipbuilding design practices, sheet metal fabrication and installation drawings do not contain the exacting detail that is in structural and mechanical systems and in many instances the final installation details. Routings and in some cases fabrication details are left to the knowledge and skill of the journeyman.
2. Ventilation systems, particularly ducting, is more susceptible to damage than most other systems, during the final outfitting stages of ship completion and a ready supply of replacement pieces is necessary.

Table 8-4. Comparison of Machine versus Man Sheet Metal Fabrication

WIEDEMATIC		MANUAL	
225 PCS / SHIFT AVG		15 PCS/SHIFT X 15 MEN	
58,500 PCS/YR			
BUDGETARY COST	\$ 127,720	BAND SAW STD. SPD	5,000
ECONOMIC LIFE	10 YRS	BAND SAW VAR. SPD	5,000
ANNUAL DEPRECIATION	12,772	CIRCLE SHEAR	5,000
		TWO NIBBLERS AT 5K	10,000
		FOUR DRILL PRESS AT 5K	20,000
		TWO PUNCH PRESS AT 5K	10,000
		15 LAYOUT TABLES AT \$300	4,500
		BUDGETARY COST	59,500
		ECONOMIC LIFE	15 YRS
		ANNUAL DEPRECIATION	3,967
TOOL COST	10,000	TOOL COST	5,967
MAINTENANCE PARTS	5,000	MAINTENANCE PARTS	1,488
LABOR 1/4 MAN YR	5,200	LABOR MAINTENANCE	5,200
1 1/2 MAN YRS	<u>31,200</u>	LABOR OPERATORS	<u>312,000</u>
TOTAL	\$ 64,172/YR	TOTAL	\$ 328,605/YR
TAPE SYSTEM	69,167		
ECONOMIC LIFE	10 YRS		
TOTAL ANNUAL COST	\$ 71,089		
COST/PIECE	\$ 1.22	COST/PIECE	\$ 5.62

## 8. 7.2 The Spiro-Matic Tube Forming and Duct Forming Machine

The Spiro- Matic Tube Forming machine is designed for continuous production of circular tubes, cut to exact predetermined length. Companion to the Spiro-Matic tube forming machine is the Spiro Duct Former. This machine transforms circular spiral tubes produced by the Spiro-Matic Tube Forming Machine into flat-oval ducting (see figures 8-8 and 8-9).

### a. Operation

The machine is fully automatic and is operated from a control panel by a single operator. The material is fed into the machine from a coil of sheet metal strip mounted on a pedestal. Once the desired diameter of tubing has been selected, the proper dies installed, the operator dials in the length(s) of tubing required,. and presses the start button, the tubing is formed, cut to length(s), rolls away from the guide track by gravity, and the machine shuts itself off.

### b. Capacity

The tube forming machine forms circular spiral tubing from 2 to 50" in diameter, and 1-inch increments up to 10 inches and in 2-inch increments 10 inches and up.

The tube is produced at a rate of 134 up to 2171 feet per hour depending upon the size of tubing to be fabricated.

The machine can be "set up" for size changes in 5 minutes.

The duct former is a completely automatic option to the tube former and is operated from a pushbutton control panel and is equipped with a special overhead traveling crane with supporting frame and grab device for duct handling. The duct former uses the circular duct as "raw" material and converts it to a variety of flat oval ducts to meet the existing requirement. (See Figure 8.8).

c. Cost Comparison

A cost comparison was made between the manual method of duct fabrication vs. the machine method. The cost per linear foot of duct produced by the manual method is \$1.59 and the cost per linear foot by the machine method is \$0.63. (Ref Table No. 8-5).

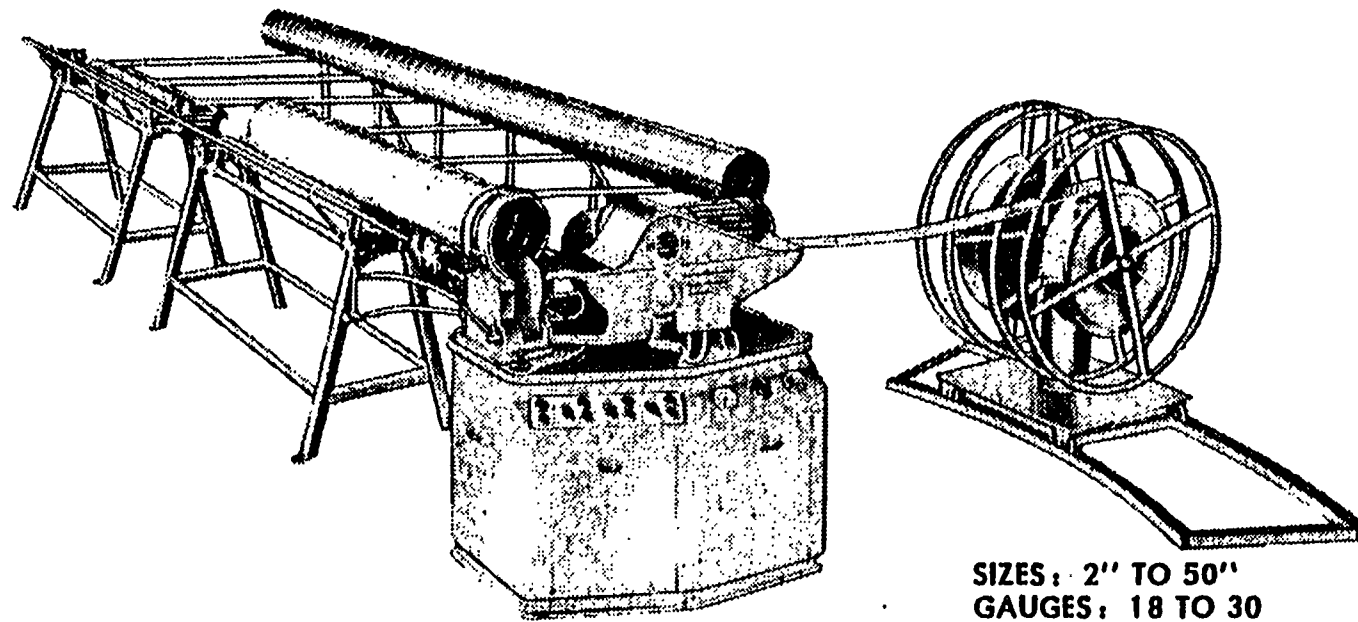
## 8.8 WELTY-WAY AUTOMATIC SHEAR

8.8.1 The Welty - Way Shear is an electro-pneumatically operated power shear that is designed for completely automated shearing of sheet metal of up to 14-gauge in thickness with an exceptional degree of accuracy and speed.

The raw material is fed into the machine from one of four coils of four feet wide sheet metal which are positioned on a coil rack. The coils of material average 3400 pounds each and are 16-, 18-, 20- and 22-gauge material which are the most commonly used thicknesses in shipbuilding sheet metal shops.

### 8. 8.2 Operation

The machine requires one operator, but for periodic loading of new coils two men are used. To shear raw material into pieces the



SIZES: 2" TO 50"  
GAUGES: 18 TO 30

Figure 8-8. The Spiro-Matic Tube Forming Machine

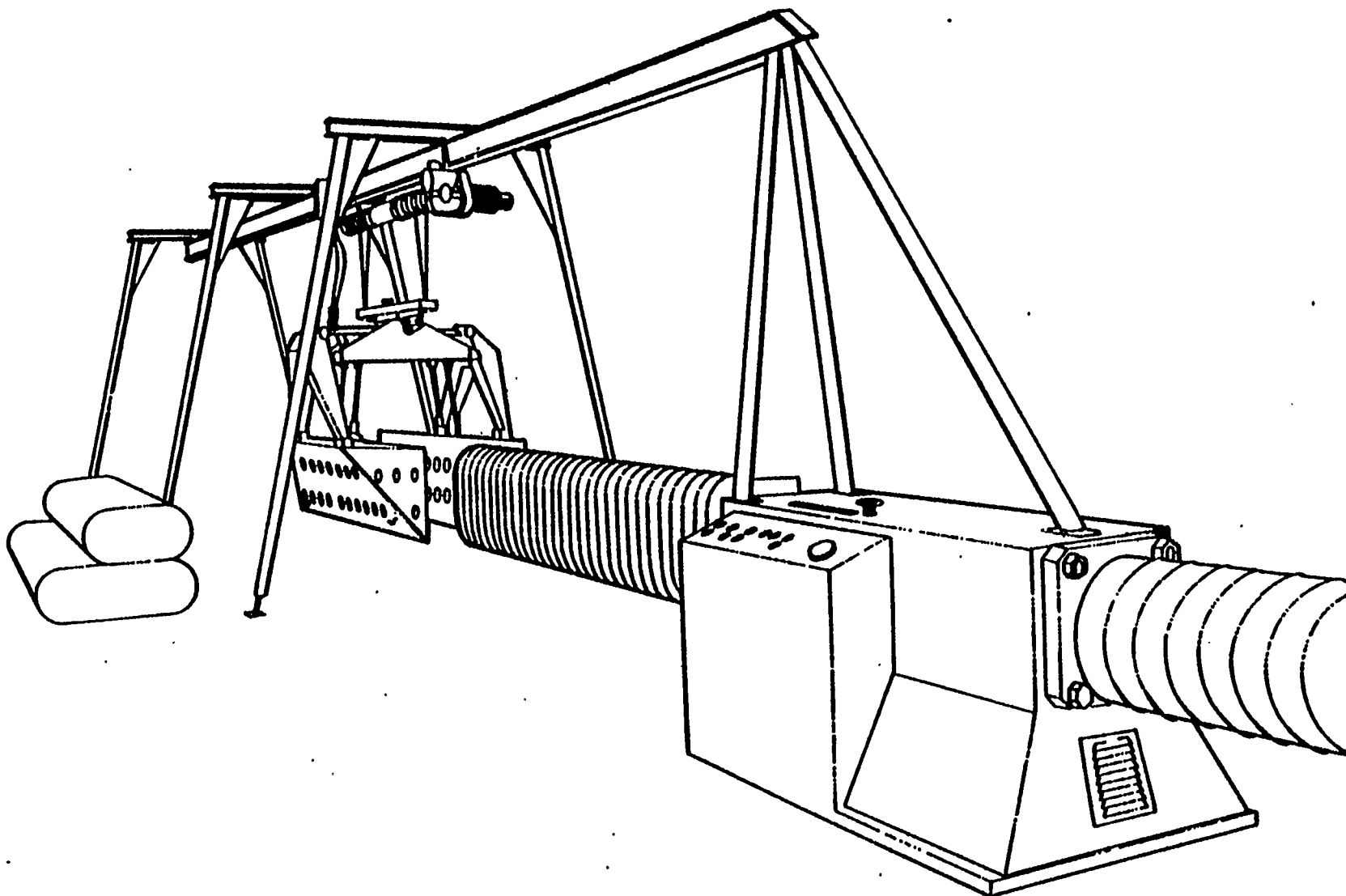


Figure 8-9.. Spiro-Matic Duct Former

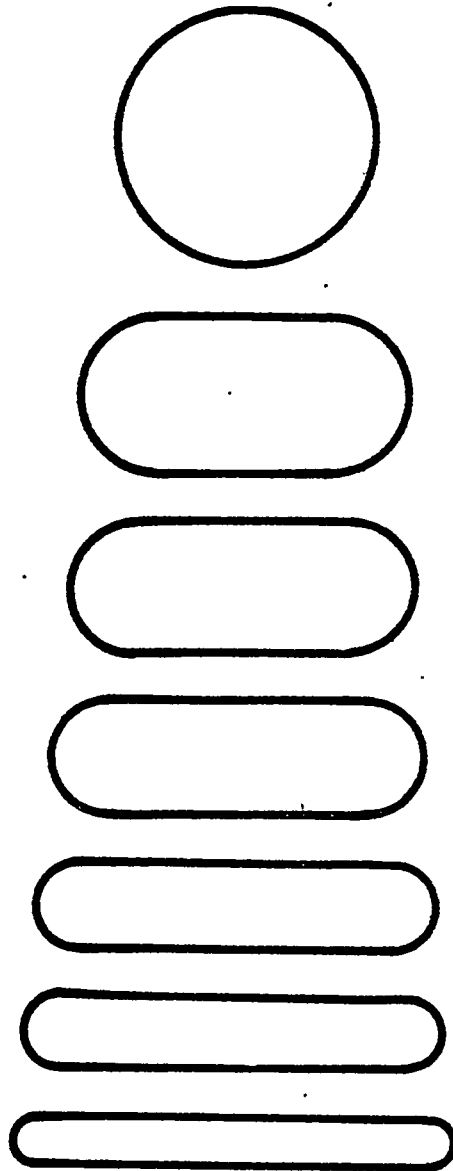


Figure 8-11. Typical Variations of Flat-Oval Duct  
That Can Be Formed From Circular Tube

Table 8-5. Comparison of Machine versus Manual Duct Fabrication

S P I R O - M A T I C		M A N U A L	
10,000 FT. OF DUCT/YR/SHIFT - 1 SHIFT			
MACHINE	\$29,533	SHIP ROLL	\$14,766
TOOLING	<u>7 , 3 8 3</u>	BREAK	<u>7 . 3 8 3</u>
BUDGETARY COST	\$36,916	BUDGETARY COST	\$22,160
ECONOMIC LIFE	10 YRS	ECONOMIC LIFE	5 YRS
ANNUAL DEPRECIATION	\$ 3,692	ANNUAL DEPRECIATION	\$ 4,430
TOOL COST	<b>500</b>		
MAINTENANCE LABOR A N D P A R T S	2,000	MAINTENANCE LABOR AND PARTS	500
LABOR OPERATORS	125	LABOR OPERATORS	10,940,
12.5 HOURS	<u>        </u>	1,094 HOURS	<u>        </u>
TOTAL	\$ 6,317/YR	TOTAL	\$ 15,870/YR
COST/L:NEAR FT	\$ 0 . 6 3	COST/LINEAR FT	\$ 1.59

Table 8-5. Comparison of Machine versus Manual Duct Fabrication (Continued)

<u>MACHINES</u>	SLIP ROLL	\$10,000 IN 1969 X $\frac{158}{107}$ = \$ 14,766.36
	BREAK	\$5,000 IN 1968 X $\frac{158}{107}$ = 7,383.18
		\$22,149.53
ECONOMIC LIFE OF MACHINES = 5 YRS		
	ANNUAL DEPRECIATION	\$ 4,429.91
	1,094 HRS TO FAB 10,000 FT. @ \$10/HR	10,940.00
	ANNUAL MAINTENANCE LABOR AND PARTS	<u>5 0 0 . 0 0</u>
	TOTAL ANNUAL COST	\$ 15,869.91/YR
	$\frac{15,868.91}{10,000.00}$ = \$ 1.5870/LINEAR FOOT OF DUCT	
IF MACHINES HAVE 10 YEAR ECONOMIC LIFE, THEN		
	ANNUAL DEPRECIATION	\$ 2,214.95
	TOTAL ANNUAL COST	\$13,654.95
	$\frac{13,654.95}{10,000.00}$ = \$1.3655/LINEAR FOOT OF DUCT A	
	14% REDUCTION IN COST BY DOUBLING ECONOMIC LIFE OF MACHINES	
HOURS BASED ON 1 MAN FABRICATING 16 FT. OF DUCT EVERY 1.75 HRS OR 16 = 9.1428571 FT/HR		
		1.75

operator selects the desired thickness, inserts the edge of the coiled material into clamps on the machine bed. The size and quantity of pieces desired is dialed into the control panel and start button is depressed. The machine makes a “squaring” cut from the edge of the material and then measures and cuts the preset size and quantity of pieces in rapid succession and automatically stacks them on a wheeled table. If, due to the size of pieces cut, some scrap is generated the scrapped pieces are deposited in a scrap trough.

#### 8.8.3 Capacity

The cutting time per piece varies with the size, but as an example if the parts are 12” long the machine cuts 125 parts per minute. If the parts are 24” long the machine cuts 80 pieces per minute. The machine will cut mild steel of up to 14-gauge.

#### 8.8.4 Cost Comparison

Table No. 8-6 draws a cost comparison between shearing pieces by the manual method vs. the automated method. The cost per piece of manual parts is \$3.52 and the cost per piece by the machine method is \$0.40.

### 8.9 SUMMARY AND DISCUSSION

An enumerated summary and discussion of the findings of this study, including observations made during research, are presented here for consideration:

- a. Series production of ships could increase the workload of the manufacturing shops of the producing shipyard. The

Table 8-6.

Table 8-6.

COMPARISON OF MACHINE VERSUS MANUAL SHEET METAL SHEARING			
Welty-Way Automatic Shear		Manual	
17,010 pieces/yr/shift - 1 shift			
Machine	\$39,233	Power Shear	\$ 6,820
Tooling	1,177		
Budgetary Cost	\$40,410	Budgetary Cost	\$ 6,820
Economic Life	10 yrs	Economic Life	10 yrs
Annual Depreciation	\$ 4,041	Annual Depreciation	\$ 682
Maintenance Labor & Parts	500	Maintenance Labor - 17 hrs	1,780
		Maintenance Parts	200
Labor 218 hrs	2,180	Labor 3,402 hrs	34,020
TOTAL	\$ 6,721/yr	TOTAL	\$36,682
Cost/piece	\$ 0.40	20% waste matl cost	23,298
		Scrap sale	(2,468)
w/o slitting feature		Cost/piece	\$ 3.53

severity of this impact would depend upon the following items:

- (1) The schedule and size of lot release of parts required in large quantities
  - (2) To what degree the shops have been modernized with machines of high production capabilities
  - (3) The availability of skilled craftsmen in sufficient numbers if machines have not been provided
  - (4) Is adequate floor space available in the shop for additional work stations if the manual method is used
  - (5) The availability of production assistance from outside sources (subcontractors).
- b. It is a known fact that in the U.S. shipbuilding industry skilled craftsmen in the numbers required are not currently available on the labor market and the situation has grown steadily worse in recent years.
- c. Due to rapid advances in technology during the past decade, there are machines of high volume production capacity available to meet nearly all shipyard shop production requirements.
- d. Many of these machines were developed for shipyard use and can be used "as is" to increase shipyard shop productivity, while others were developed primarily for other industries,

but with some modification can be readily adapted to meet shipyard requirements.

- e. Many of these specialized machines will produce a volume of parts and/or material that, if operated to full capacity, will by far exceed the production rate required by a single shipyard. In these specific instances, alternative solutions are possible:

- (1) Invest in the machine with the pre-determined purpose of part time use, as the lower cost of parts even at a reduced capacity will offset capital out-lay (Ref Table No. 8.; Spiro-Matic).
- (2) Invest in the machine and offer the surplus production to other companies that use the same item, at profitable but competitive prices.
- (3) Do not invest in the machine and purchase the parts and/or materials from a company that opted for (2) above.

This alternate has additional beneficial potential, as it will release much needed craftsmen for tasks that have not been automated or mechanized, and will make shop space available for other requirements.

- f. Most of the semi - and fully automatic machines can be operated by employees with less training and skill than is required for the manual methods.

- g. The initial capital investment for machines by far exceeds the cost of preparing for the manual methods, but the pay-back potential in cases studied, offsets the expenditure (Ref cost comparisons in Tables 8-1, 8-4, 8-5, and 8-6 on pages 8-14, 8-33, 8-39 and 8-42 respectively).
- h. In many geographical areas with high concentrations of heavy industry such as shipbuilding, there are located smaller manufacturing concerns whose primary purpose is to support the larger companies that design and produce a major product. These smaller companies specialize in high volume production of parts and materials that are used in large quantities by the major companies. These smaller concerns, by concentrating production on a specific item, can afford to make capital investments in machines that represent the latest "state of the art" in that particular field, i. e., pipe hangers, sheet metal ducts, elbows, electrical kick pipes, manhole covers and collars, chocks, etc.

A shipyard contemplating series production should have its make or buy committee survey and evaluate the capabilities of such small concerns to determine the profitability of purchasing these items as opposed to in-house manufacture.

By this practice, a shipyard engaged in series production can to a certain degree, reap the benefits of high production machines without, major capital investment that would otherwise be required, for in many cases these parts can be purchased at a cost that is lower than in-house production by manual methods.

## 8.10 RECOMMENDATIONS

The recommendations to be made in regard to machine applications are:

1. Determine the production rate and/or schedule to be reached.
2. Survey and analyze the current capability and production rate of shop equipment. If the manual method is being used to produce any pacing item, determine to what extent the employees and work stations must be increased to meet the established schedule.
3. Identify areas where production rates must be increased.
4. Survey the suppliers of production machines in order to determine the latest "state of the art" that exists to produce specific items.
5. Modernize the shops by acquiring entirely new high production systems or modify existing equipment where possible to increase productivity.
6. Recognizing that adequate capital is not always available to accomplish total modernization, an alternate solution is offered. That is to subcontract high use items to shops that specialize in certain items, i. e., sheet metal ducting, pipe hangers and clamps, sheet metal parts in the flat pattern, electrical kick pipes, manhole covers and collars. For series production this is particularly attractive, for in addition to obtaining needed parts at a cost below that of in-house production by manual methods, valuable shop

space is made available for other uses, and even more valuable craftsmen can be assigned to tasks that cannot be accomplished by other means.

This practice in the writer's opinion cannot be stressed too highly, or limited in scope to only a few high use detail parts. It is strongly recommended that in order to attain the maximum production from an existing yard by series production that a major effort be made to sub-contract as much of the entire ship as possible and practical. The shipyard with the primary contract, would according to this theory become the design, assembly, launch, and outfitting yard. The potential advantages of this action are as follows:

- a. The demand for skilled manpower would be dispersed over a wider region.
- b. The producing yard could make optimum use of existing shop space, and outside areas, for assembly jigs and fixtures required for stationized assembly line processes:
- c. Capital funds that otherwise would be expended for modernization of shops, for machines and fabrication equipment could be concentrated on jigs, fixtures, and the increased crane and/or heavy lift-move capacity that, according to the study, would be required for series production.

- d. A recommended list of types of items that could be evaluated for possible sub-contracts are as follows:
- (1) Major pipe fabrications and components.
  - (2) Sheet metal assemblies, including complete systems.
  - (3) Flat panel, structural assemblies for the midbody, bow and stern sections, to be constructed in-house. (Structural assembly sections would normally be placed where water transportation is available).
  - (4) L/T beam stiffener sections.
  - (5) If the super structure or house is designed using the containerized concept, the modules could be fabricated and outfitted elsewhere and shipped to assembly/erection point.
  - (6) All masts, hatch covers and coamings.
  - (7) Vertical and inclined ladders.

This list of recommended candidate items for subcontracts is by no means to be construed as a complete or limited list of items, but as general examples offered for consideration. In the final analysis the producing yard would select the item(s) to be subcontracted.

However, the results of this overall Ustudy indicate that if an active sub-contracting program is instituted, the timely flow of completed parts and assemblies into the assembly yard would increase the production potential of the primary shipyard, at a lower cost than could otherwise be attained.